Project Dissertation Report on

FACIAL DETECTION and RECOGNITION

CONCEPT RESEARCH AND DETAILED STUDY

Submitted By

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Candidate's Declaration

I hereby, certify that the work which is being presented in the report entitled, "FACIAL DETECTION AND RECOGNITION-A DETAILED SURVEY" , in the partial fulfillment of the requirements for the award of the degree of Masters of Business Administration specialised in IT and operations, submitted in the MBA department, Delhi School of Management, affiliated to Delhi Technological University, Rohini, Delhi (India), is an authentic record of my own work carried out during session 2020-22,under the supervision of Dr. Abhinav Chaudhary, Assistant Professor, MBA department, Delhi School of Management.

The matter embodied in this project report has not been submitted by me for the award of any other degree or diploma.

Dated: May 3rd, 2020 **Muskan Gupta**

CERTIFICATE

This is to certify that the project work "FACIAL DETECTION AND RECOGNITION-A DETAILED SURVEY" is a bonafide record of work done by Muskan Gupta under our guidance in partial fulfillment of the requirement for the MBA project as per the record of Delhi Technological University, Rohini in academic session of 2020-22 at Delhi School of Management, Rohini.

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EXECUTIVE SUMMARY

Face recognition has been one of the most interesting and important research fields in the past two decades. The reasons come from the need of automatic recognitions and surveillance systems, the interest in human visual system on face recognition, and the design of human-computer interface, etc. These researches involve knowledge and researchers from disciplines such as neuroscience, psychology, computer vision, pattern recognition, image processing, and machine learning, etc. A bunch of papers have been published to overcome different factors (such as illumination, expression, scale, pose, etc.) and achieve better recognition rate, while there is still no robust technique against uncontrolled practical cases which may involve kinds of factors simultaneously. In this report, we'll go through general ideas and structures of recognition, important issues and factors of human faces, critical techniques and algorithms, and finally give a conclusion.

Chapter 1: INTRODUCTION

1.Facial Detection

Face detection is a computer technology being used in a variety of applications that identifies human faces in digital images. Face detection also refers to the psychological process by which humans locate and attend to faces in a visual scene.

Automatic face detection

Face detection can be regarded as a specific case of object-class detection. In object-class detection, the task is to find the locations and sizes of all objects in an image that belong to a given class. Examples include upper torsos, pedestrians, and cars.

Face-detection algorithms focus on the detection of frontal human faces. It is analogous to image detection in which the image of a person is matched bit by bit. Image matches with the image stores in database. Any facial feature changes in the database will invalidate the matching process.

A reliable face-detection approach based on genetic algorithm and the eigen-face technique:

Firstly, the possible human eye regions are detected by testing all the valley regions in the gray-level image. Then the genetic algorithm is used to generate all the possible face regions which include the eyebrows, the iris, the nostril and the mouth corners.

Each possible face candidate is normalized to reduce both the lighting effect, which is caused by uneven illumination; and the shirring effect, which is due to head movement. The fitness value of each candidate is measured based on its projection on the eigen-faces. After a number of iterations, all the face candidates with a high fitness value are selected for further verification. At this stage, the face symmetry is measured and the existence of the different facial features is verified for each face candidate.

2. Facial Recognition

A facial recognition system is a technology capable of identifying or verifying a person from a digital frame or a video frame from a video source. There are multiple methods in which facial recognition systems work, but in general, they work by comparing selected facial features from given image with faces within a database. It is also described as a Biometric Artificial Intelligence based application that can uniquely identify a person by analyzing patterns based on the person's facial textures and shape.

While initially a form of computer application, it has seen wider uses in recent times on mobile platforms and in other forms of technology, such as robotics. It is typically used as access control in security systems and can be compared to other biometrics, such as fingerprint or eye iris recognition systems. Although the accuracy of facial recognition system as a biometric technology is lower than iris recognition and fingerprint recognition, it is widely adopted due to its contactless and non-invasive process. Recently, it has also become popular as a commercial identification and marketing tool. Other applications include advanced human-computer interaction, video surveillance, automatic indexing of images, and video database, among others.

3. Anti- facial recognition systems

In January 2013 Japanese researchers from the National Institute of Informatics created 'privacy visor' glasses that use nearly infrared light to make the face underneath it unrecognizable to face recognition software. The latest version uses a titanium frame, light-reflective material and a mask which uses angles and patterns to disrupt facial recognition technology through both absorbing and bouncing back light sources. Some projects use adversarial machine learning to come up with new printed patterns that confuse existing face recognition software.

Another method to protect from facial recognition systems are specific haircuts and make-up patterns that prevent the used algorithms to detect a face, known as computer vision dazzle. Incidentally, the makeup styles popular with Juggalos can also protect against facial recognition.

4. Process of Automatic Face Recognition

A general statement of the problem of machine recognition of faces can be formulated as follows: given still or video images of a scene, identify or verify one or more persons in the scene using a stored database of faces.

Face recognition is often described as a process that first involves four steps; they are: face detection, face alignment, feature extraction, and finally face recognition.

i. Face Detection. Locate one or more faces in the image and mark with a bounding box.
ii. Face Alignment. Normalize the face to be consistent with the database, such as geometry and photometrics.
iii. Feature Extraction. Extract features from the face that can be used for the recognition task.
iv. Face Recognition. Perform matching of the face against one or more known faces in a prepared database.

A given system may have a separate module or program for each step, which was traditionally the case, or may combine some or all of the steps into a single process.

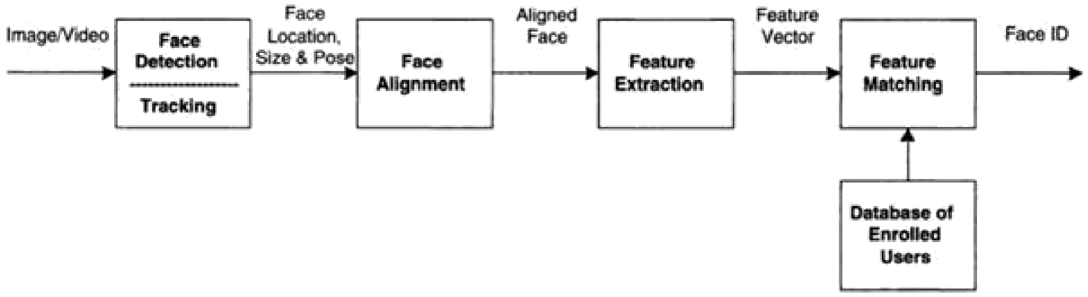


Fig. 1.2. Face recognition processing flow.

5. Market Overview

The Facial Recognition Market was valued at USD 3.72 billion in 2020, and is projected to be valued at USD 11.62 billion by 2026, registering a CAGR of approximately 21.71% over the forecast period (2021 - 2026). Since the outbreak of Covid-19, vendors across the world have already upgraded their algorithms to accommodate new set of changes and norms. For instance, according to a study by National Institute of Standards and Technology (NIST) found that, several algorithms, reconfigured since the pandemic began, make far fewer mistakes when analysing masked faces. In some cases, error rates were ten times better than before.

Moreover, during the COVID-19 outbreak in China, authorities have used facial recognition, combined with infrared cameras, to recognize infected people. Also, Chinese intelligent interaction company, Hanwang Technology, developed a facial recognition technology that can identify people wearing masks, as the use of masks hindered the operation of the technology in the country.

- China is one of the major consumers and exporters of the facial recognition technology, as the law and enforcement, along with various government bodies in the country, adopted surveillance technologies. Currently, the country has the most extensive public surveillance system. According to Comparitech, in China, the number of CCTV cameras ranges from 200 million to 626 million by 2020.
- Furthermore, in March 2020, India approved the deployment of its Automated Facial Recognition System (AFRS) across the nation by early 2021, allowing facial biometrics to be extracted from video and CCTV which will be matched with the image of individuals' photos whose identity information are housed in a database by the National Crime Records Bureau under the purview of the Minister of State for Home Affairs.
- Also, the Indian government's Aadhaar project is one of the largest biometric databases globally, and it is currently held by over 95% of the country's population, which is over 1.3 billion. The UIDAI contains a citizen's fingerprint, facial recognition, and iris. Currently, citizens in the country are actively using the technology for authentication, primarily to avail of various government benefits, processes, and facilities.
- Government initiatives are expected to contribute to the significant growth of such technologies. For instance, the US government is planning to reshape airport security through facial recognition, to register and identify the visitors. Additionally, several North American Free Trade Agreement (NAFTA) member banks mandated the use of facial and voice recognition technologies for online identity verification. Companies have been collaborating with federal governments to implement the technology for their surveillance and identity management. The Chinese e-commerce giant, Alibaba, invested USD 600 million in SenseTime, a Hong Kong-based company that provides facial recognition software to businesses and governments across China.
- The increasing use of technology in the different end-user industries is expected to expand the market over the coming years. The applications are increasing in healthcare, automotive, smart home, access control, and many more.

6. Scope of the Report

Facial recognition is a biometric software capable of uniquely identifying, recognizing, and authenticating a person by comparing and analyzing patterns based on the facial contours of the subject. The report into consideration deals with facial recognition software in line with technologies like 3D, 2D facial recognition, and facial analytics. The study under consideration provides applications, market trends, influencing factors, and growth data of the software by end-users, such as security and law enforcement, healthcare, retail, and other end users.

***Chapter 2*:** LITERATURE REVIEW

During 1964 and 1965, Bledsoe, along with Helen Chan and Charles Bisson, worked on using the computer to recognize human faces (Bledsoe 1966a, 1966b; Bledsoe and Chan 1965). He was proud of this work, but because the funding was provided by an unnamed intelligence agency that did not allow much publicity, little of the work was published. Based on the available references, it was revealed that the Bledsoe's initial approach involved the manual marking of various landmarks on the face such as the eye centers, mouth, etc., and these were mathematically rotated by computer to compensate for pose variation.The distances between landmarks were also automatically computed and compared between images to determine identity.

Given a large database of images (in effect, a book of mug shots) and a photograph, the problem was to select from the database a small set of records such that one of the image records matched the photograph. The success of the method could be measured in terms of the ratio of the answer list to the number of records in the database. Bledsoe (1966a) described the following difficulties:

This recognition problem is made difficult by the great variability in head rotation and tilt, lighting intensity and angle, facial expression, aging, etc. Some other attempts at face recognition by machine have allowed for little or no variability in these quantities. Yet the method of correlation (or pattern matching) of unprocessed optical data, which is often used by some researchers, is certain to fail in cases where the variability is great. In particular, the correlation is very low between two pictures of the same person with two different head rotations.

This project was labeled man-machine because the human extracted the coordinates of a set of features from the photographs, which were then used by the computer for recognition. Using a graphics tablet (GRAFACON or RAND TABLET), the operator would extract the coordinates of features such as the center of pupils, the inside corner of eyes, the outside corner of eyes, point of widows peak, and so on. From these coordinates, a list of 20 distances, such as the width of mouth and width of eyes, pupil to pupil, were computed. These operators could process about 40 pictures an hour. When building the database, the name of the person in the photograph was associated with the list of computed distances and stored in the computer. In the recognition phase, the set of distances was compared with the corresponding distance for each photograph, yielding a distance between the photograph and the database record. The closest records are returned.

Because it is unlikely that any two pictures would match in head rotation, lean, tilt, and scale (distance from the camera), each set of distances is normalized to represent the face in a frontal orientation.

To accomplish this normalization, the program first tries to determine the tilt, the lean, and the rotation. Then, using these angles, the computer undoes the effect of these transformations on the computed distances. To compute these angles, the computer must know the three-dimensional geometry of the head. Because the actual heads were unavailable, Bledsoe (1964) used a standard head derived from measurements on seven heads.

After Bledsoe left PRI in 1966, this work was continued at the Stanford Research Institute, primarily by Peter Hart. In experiments performed on a database of over 2000 photographs, the computer consistently outperformed humans when presented with the same recognition tasks (Bledsoe 1968). Peter Hart (1996) enthusiastically recalled the project with the exclamation, "It really worked!"

By about 1997, the system developed by Christoph von der Malsburg and graduate students of the University of Bochum in Germany and the University of Southern California in the United States outperformed most systems with those of Massachusetts Institute of Technology and the University of Maryland rated next. The Bochum system was developed through funding by the United States Army Research Laboratory. The software was sold as ZN-Face and used by customers such as Deutsche Bank and operators of airports and other busy locations. The software was "robust enough to make identifications from less-than-perfect face views. It can also often see through such impediments to identification as mustaches, beards, changed hairstyles and glasses—even sunglasses".

In 2006, the performance of the latest face recognition algorithms was evaluated in the Face Recognition Grand Challenge (FRGC). High-resolution face images, 3-D face scans, and iris images were used in the tests. The results indicated that the new algorithms are 10 times more accurate than the face recognition algorithms of 2002 and 100 times more accurate than those of 1995. Some of the algorithms were able to outperform human participants in recognizing faces and could uniquely identify identical twins.

U.S. Government-sponsored evaluations and challenge problems have helped spur over two orders-of-magnitude in face-recognition system performance. Since 1993, the error rate of automatic face-recognition systems has decreased by a factor of 272. The reduction applies to systems that match people with face images captured in studio or mugshot environments. In Moore's law terms, the error rate decreased by one-half every two years.
Low-resolution images of faces can be enhanced using face hallucination.

Techniques for face acquisition

Essentially, the process of face recognition is performed in two steps. The first involves feature extraction and selection and the second is the classification of objects.Later developments introduced varying technologies to the procedure. Some of the most notable include the following techniques:

Traditional

Some face recognition algorithms identify facial features by extracting landmarks, or features, from an image of the subject's face. For example, an algorithm may analyze the relative position, size, and/or shape of the eyes, nose, cheekbones, and jaw. These features are then used to search for other images with matching features.

Other algorithms normalize a gallery of face images and then compress the face data, only saving the data in the image that is useful for face recognition. A probe image is then compared with the face data. One of the earliest successful systems is based on template matching techniques applied to a set of salient facial features, providing a sort of compressed face representation.

Recognition algorithms can be divided into two main approaches: geometric, which looks at distinguishing features, or photometric, which is a statistical approach that distills an image into values and compares the values with templates to eliminate variances. Some classify these algorithms into two broad categories: holistic and feature-based models. The former attempts to recognize the face in its entirety while the feature-based subdivide into components such as according to features and analyze each as well as its spatial location with respect to other features.

Popular recognition algorithms include principal component analysis using eigenfaces, linear discriminant analysis, elastic bunch graph matching using the Fisherface algorithm, the hidden Markov model, the multilinear subspace learning using tensor representation, and the neuronal motivated dynamic link matching.

3-Dimensional recognition

Three-dimensional face recognition technique uses 3D sensors to capture information about the shape of a face. This information is then used to identify distinctive features on the surface of a face, such as the contour of the eye sockets, nose, and chin.

One advantage of 3D face recognition is that it is not affected by changes in lighting like other techniques. It can also identify a face from a range of viewing angles, including a profile view.

Three-dimensional data points from a face vastly improve the precision of face recognition. 3D research is enhanced by the development of sophisticated sensors that do a better job of capturing 3D face imagery. The sensors work by projecting structured light onto the face. Up to a dozen or more of these image sensors can be placed on the same CMOS chip—each sensor captures a different part of the spectrum.

Even a perfect 3D matching technique could be sensitive to expressions. For that goal a group at the Technion applied tools from metric geometry to treat expressions as isometries.

A new method is to introduce a way to capture a 3D picture by using three tracking cameras that point at different angles; one camera will be pointing at the front of the subject, second one to the side, and third one at an angle. All these cameras will work together so it can track a subject's face in real time and be able to face detect and recognize.

Skin texture analysis

Another emerging trend uses the visual details of the skin, as captured in standard digital or scanned images. This technique, called Skin Texture Analysis, turns the unique lines, patterns, and spots apparent in a person's skin into a mathematical space.

Surface Texture Analysis works much the same way facial recognition does. A picture is taken of a patch oasda distinguish any lines, pores and the actual skin texture. It can identify the contrast between identical pairs, which are not yet possible using facial recognition software alone.

Tests have shown that with the addition of skin texture analysis, performance in recognizing faces can increase 20 to 25 percent.

Facial recognition combining different techniques

As every method has its advantages and disadvantages, technology companies have amalgamated the traditional, 3D recognition and Skin Textual Analysis, to create recognition systems that have higher rates of success.

Combined techniques have an advantage over other systems. It is relatively insensitive to changes in expression, including blinking, frowning or smiling and has the ability to compensate for mustach or beard growth and the appearance of eyeglasses. The system is also uniform with respect to race and gender.

Thermal cameras

A different form of taking input data for face recognition is by using thermal cameras, by this procedure the cameras will only detect the shape of the head and it will ignore the subject accessories such as glasses, hats, or makeup. Unlike conventional cameras, thermal cameras can capture facial imagery even in low-light and night time conditions without using a flash and exposing the position of the camera. However, a problem with using thermal pictures for face recognition is that the databases for face recognition is limited. Diego Socolinsky and Andrea Selinger (2004) research the use of thermal face recognition in real life and operation sceneries, and at the same time build a new database of thermal face images. The research uses low-sensitive, low-resolution ferroelectric electrics sensors that are capable of acquiring long-wave thermal infrared (LWIR). The results show that a fusion of LWIR and regular visual cameras has greater results in outdoor probes. Indoor results show that visual has a 97.05% accuracy, while LWIR has 93.93%, and the fusion has 98.40%, however on the outdoor proves visual has 67.06%, LWIR 83.03%, and fusion has 89.02%. The study used 240 subjects over a period of 10 weeks to create a new database. The data was collected on sunny, rainy, and cloudy days.

In 2018, researchers from the U.S. Army Research Laboratory (ARL) developed a technique that would allow them to match facial imagery obtained using a thermal camera with those in databases that were captured using a conventional camera. This approach utilized artificial intelligence and machine learning to allow researchers to visibly compare conventional and thermal facial imagery. Known as a cross-spectrum synthesis method due to how it bridges facial recognition from two different imaging modalities, this method synthesize a single image by analyzing multiple facial regions and details. It consists of a non-linear regression model that maps a specific thermal image into a corresponding visible facial image and an optimization issue that projects the latent projection back into the image space.

ARL scientists have noted that the approach works by combining global information (i.e. features across the entire face) with local information (i.e. features regarding the eyes, nose, and mouth). In addition to enhancing the discriminability of the synthesized image, the facial recognition system can be used to transform a thermal face signature into a refined visible image of a face. According to performance tests conducted at ARL, researchers found that the multi-region cross-spectrum synthesis model demonstrated a performance improvement of about 30% over baseline methods and about 5% over state-of-the-art methods. It has also been tested for landmark detection for thermal images.

Application

Social media

Social media platforms have adopted facial recognition capabilities to diversify their functionalities in order to attract a wider user base amidst stiff competition from different applications.

Founded in 2013, Looksery went on to raise money for its face modification app on Kickstarter. After successful crowdfunding, Looksery launched in October 2014. The application allows video chat with others through a special filter for faces that modifies the look of users. While there is image augmenting applications such as FaceTune and Perfect365, they are limited to static images, whereas Looksery allowed augmented reality to live videos. In late 2015, SnapChat purchased Looksery, which would then become its landmark lenses function.

SnapChat's animated lenses, which used facial recognition technology, revolutionized and redefined the selfie, by allowing users to add filters to change the way they look. The selection of filters changes every day, some examples include one that makes users look like an old and wrinkled version of themselves, one that airbrushes their skin, and one that places a virtual flower crown on top of their head. The dog filter is the most popular filter that helped propel the continual success of SnapChat, with popular celebrities such as Gigi Hadid, Kim Kardashian and the likes regularly posting videos of themselves with the dog filter.

DeepFace is a deep learning facial recognition system created by a research group at Facebook. It identifies human faces in digital images. It employs a nine-layer neural net with over 120 million connection weights, and was trained on four million images uploaded by Facebook users. The system is said to be 97% accurate, compared to 85% for the FBI's Next Generation Identification system. One of the creators of the software, Yaniv Taigman, came to Facebook via their acquisition of Face.com.

ID verification

The emerging use of facial recognition is in the use of ID verification services. Many companies and others are working in the market now to provide these services to banks, ICOs, and other e-businesses.

Face ID

Apple introduced Face ID on the flagship iPhone X as a biometric authentication successor to the Touch ID, a fingerprint based system. Face ID has a facial recognition sensor that consists of two parts: a "Romeo" module that projects more than 30,000 infrared dots onto the user's face, and a "Juliet" module that reads the pattern. The pattern is sent to a local "Secure Enclave" in the device's central processing unit (CPU) to confirm a match with the phone owner's face. The facial pattern is not accessible by Apple. The system will not work with eyes closed, in an effort to prevent unauthorized access.

The technology learns from changes in a user's appearance, and therefore works with hats, scarves, glasses, and many sunglasses, beard and makeup.

It also works in the dark. This is done by using a "Flood Illuminator", which is a dedicated infrared flash that throws out invisible infrared light onto the user's face to properly read the 30,000 facial points.

Deployment in security services

Commonwealth

The Australian Border Force and New Zealand Customs Service have set up an automated border processing system called SmartGate that uses face recognition, which compares the face of the traveller with the data in the e-passport microchip. All Canadian international airports use facial recognition as part of the Primary Inspection Kiosk program that compares a traveler face to their photo stored on the ePassport. This program first came to Vancouver International Airport in early 2017 and was rolled up to all remaining international airports in 2018–2019. The Tocumen International Airport in Panama operates an airport-wide surveillance system using hundreds of live face recognition cameras to identify wanted individuals passing through the airport.

Police forces in the United Kingdom have been trialling live facial recognition technology at public events since 2015. However, a recent report and investigation by Big Brother Watch found that these systems were up to 98% inaccurate.

In May 2017, a man was arrested using an automatic facial recognition (AFR) system mounted on a van operated by the South Wales Police. Ars Technica reported that "this appears to be the first time [AFR] has led to an arrest".

Live facial recognition has been trialled since 2016 in the streets of London. It will be used on a regular basis from Metropolitan Police from beginning of 2020.

Chapter 3: FACE DETECTION

1.Knowledge-based methods

These rule-based methods encode human knowledge of what constitutes a typical face. Usually, the rules capture the relationships between facial features. These methods are designed mainly for face localization, which aims to determine the image position of a single face. In this subsection, we introduce two examples based on hierarchical knowledge-based method and vertical / horizontal projection.

2.Hierarchical knowledge-based method

This method is composed of the multi-resolution hierarchy of images and specific rules defined at each image level [4]. The hierarchy is built by image sub-sampling. The face detection procedure starts from the highest layer in the hierarchy (with the lowest resolution) and extracts possible face candidates based on the general look of faces. Then the middle and bottom layers carry rule of more details such as the alignment of facial features and verify each face candidate. This method suffers from many factors described in Section 3 especially the RST variation and doesn't achieve high detection rate (50 true positives in 60 test images), while the coarse-to-fine strategy does reduce the required computation and is widely adopted by later algorithms.

3.Horizontal / vertical projection

This method uses the fairly simple image processing technique, the horizontal and vertical projection [6]. Based on the observations that human eyes and mouths have lower intensity than other parts of faces, these two projections are performed on the test image and local minimums are detected as facial feature candidates which together constitute a face candidate. Finally, each face candidate is validated by further detection rules such as eyebrow and nostrils.

4.Face Detection Using Color Information

In this work, Hsu et al [7] proposed to combine several features for face detection. They used color information for skin-color detection to extract candidate face regions. In order to deal with different illumination conditions, they extracted the 5% brightest pixels and used their mean color for lighting compensation. After skin-color detection and skin-region segmentation, they proposed to detect invariant facial features for region verification. Human eyes and mouths are selected as the most significant features of faces and two detection schemes are designed based on chrominance contrast and morphological operations, which are called "eyes map" and "mouth map". Finally, we form the triangle between two eyes and a mouth and verify it based on (i) luminance variations and average gradient orientations of eye and mouth blobs, (ii) geometry and orientation of the triangle, and (iii) the presence of a face boundary around the triangle. The regions pass the verification are denoted as faces and the Hough transform are performed to extract the best-fitting ellipse to extract each face. This work gives a good example of how to combine several different techniques together in a cascade fashion. The lighting compensation process doesn't have a solid background, but it introduces the idea that despite modelling all kinds of illumination conditions based on complicated probability or classifier models, we can design an illumination-adaptive model which modifies its detection threshold based on the illumination and chrominance properties of the present image.

The eyes map and the mouth map show great performance with fairly simple operations and in our recent work we also adopt their framework and try to design more robust maps.

5.Face detection based on random labelled graph matching

Leung et al. developed a probabilistic method to locate a face in a cluttered scene based on local feature detectors and random graph matching [8]. Their motivation is to formulate the face localization problem as a search problem in which the goal is to find the arrangement of certain features that is most likely to be a face pattern. In the initial step, a set of local feature detectors is applied to the image to identify candidate locations for facial features, such as eyes, nose, and nostrils, since the feature detectors are not perfectly reliable, the spatial arrangement of the features must also be used for localize the face. The facial feature detectors are built by the multi-orientation and multi-scale Gaussian derivative filters, where we select some characteristic facial features (two eyes, two nostrils, and nose/lip junction) and generate a prototype filter response for each of them. The same filter operation is applied to the input image and we compare the response with the prototype responses to detect possible facial features. To enhance the reliability of these detectors, the multivariate-Gaussian distribution is used to represent the distribution of the mutual distances among each facial feature, and this distribution is estimated by a set of training arrangements. The facial feature detectors averagely find 10-20 candidate locations for each facial feature, and the brute-force matching for each possible facial feature arrangement is computationally very demanding. To solve this problem, the authors proposed the idea of controlled search. They set a higher threshold for strong facial feature detection, and each pair of these strong features is selected to estimate the locations of other three facial features using a statistical model of mutual distances. Furthermore, the covariance of the estimates can be computed. Thus, the expected feature locations are estimated with high probability. Constellations are formed only from candidate facial features that lie inside the appropriate locations, and the ranking of constellation is based on a probability density function that a constellation corresponds to a face versus the probability it was generated by the non-face mechanism. In their experiments, this system is able to achieve a correct localization rate of 86% for cluttered images.

6.Template matching methods

In this category, several standard patterns of a face are stored to describe the face as a whole or the facial feature separately. The correlations between an input image and the stored pattern are computed for detection. These methods have been used for both face localization and detection. The following subsection summarizes an excellent face detection technique based on deformable template matching, where the template of faces is deformable according to some defined rules and constraints.

7.Adaptive appearance model

In the traditional deformable template matching techniques, the deformation constraints are determined based on user-defined rules such as first- or second-order derivative properties. These constraints are seeking for the smooth nature or some prior knowledge, while not all the patterns we are interested in have these properties. Furthermore, the traditional techniques are mainly used for shape or boundary matching, not for texture matching.

8.Feature invariant approaches

These algorithms aim to find structural features that exist even when the pose, viewpoint, or lighting conditions vary, and then use these to locate faces. These methods are designed mainly for face localization. To distinguish from the knowledge-based methods, the feature invariant approaches start at feature extraction process and face candidates finding, and later verify each candidate by spatial relations among these features, while the knowledge-based methods usually exploit information of the whole image and are sensitive to complicated backgrounds.

Chapter 4: **DETAILS AND METHODOLOGY**

Most of the applications have large number of features set that can be used. These features causes high dimensional set that can affect negatively performance of pattern recognition, image processing, data mining, and other applications. Feature selection is a process of selecting best features from large features set to improve the quality of data. The main advantages of feature selection are removing noisy data and irrelevant the data.

In image retrieval, once the features are extracted from image database; the problem is that which features are relevant in retrieval process. It comprises high dimensionality of data that may cause 'Curse of dimensionality' problem. Our paper gives a solution to this problem by using evolutionary computation for feature selection. The two algorithms are use feature selection, namely Genetic Algorithm, and Binary Bat Algorithm; in image retrieval system.

The content based image retrieval is used in this paper which is an application of computer vision to image retrieval problem. It is allow to users to find similar images from image database according to query image on the basis of similarity in features (color, texture, and shape) that means features from query image compared with features from image database.

Images in database to find most similar images, resulting in basically linear search, which is inefficient high computationally when the image database is large. To overcome this problem, image clustering has been treated as to speed up image retrieval in large databases. We select kmeans algorithm because it is fit to cluster the large amount of data.

Here feature selection using different techniques for any applications have been used extensively mentioned in various research papers for better performance. A.Sylvia Rani et.al. describes the feature selection and performed Binary Bat Algorithm for unsupervised feature selection with k-means clustering algorithm. They used different real world datasets and shows different combinations of features are selected which have more accuracy. Also compare with other optimization algorithm. Lakshmi p.s et.al. Performed retrieval of different input query images from the image database based on texture feature. Texture feature is extracted from image using gray level co-occurrence matrix (GLCM). They approached feature selection using genetic algorithm (GA) to improve the accuracy of content based image retrieval. The results of feature selection based on the performance measures (precision and recall) showed higher accuracy of the retrieval system can obtained in lesser computation time. P.K.Bhargavi et.al. Contributes that content based image retrieval system based on the relevant feature. They used color coherence vector and Gabor wavelets feature extraction technique. For Feature Discrimination, it used maximum entropy method for transforming numerical features with nominal using Class Attribute Interdependence Maximization (CAIM) algorithm. They also analyzed proposed approach by optimizing it with the feature selection using Particle Swarm optimization (PSO) algorithm for extracting the near relevant features. The result showed effectiveness and efficiency of the proposed model is compared with other models using precision and recall. C.V. Rashmi et.al.Views that novel image retrieval using Ant Colony Optimization and Relevance Feedback. The proposed system, feature vector of the image is extracted by calculation of color correlogram, Gabor filter and edge histogram descriptors. In their model, feature selection using ACO technique to optimize the features for speed up retrieval and similarity computation. They used support vector machine (SVM) to improve efficiency of the system by using Relevance Feedback.

Clustering is used in CBIR system, Mit Patel et.al. Describes collection of features or a dataset is divided into similar image classes using clustering and classification. The clustering is done with k-means clustering, and classification is done with fuzzy rule based classification. These algorithms are based on texture and color information. In their proposed model, the result showed accuracy is increases and retrieval time is decreases. They compared with proposed model and normal model.

4.1METHODOLOGY

In this section, I am introducing methods for new proposed system. As described further the new proposed system is done with four efficient techniques such as :

1. Three Feature extractions techniques are used for colour, shape, and texture. 2. Feature selection using Genetic Algorithm.
3. Feature selection using Binary Bat Algorithm 4. Clustering technique

The following new approaches describe below:

4.1.1 Feature Extraction:

Feature extraction is most valuable operation of CBIR system. It translates the input data into set of features. In this section, we describe three feature extraction techniques for color, texture and shape which are used in our proposed CBIR system.

4.1.1.1 Colour Moment: Color moment represents characterized a color image. There are 3 different color moments: first order is mean, second order is standard deviation, and third order is skewness of color; are extracted from RGB and HSI color spaces to form an 18-dimensional, using the following mathematical formulation:

4.1.1.2 Gabor Filter: Texture feature extraction describes distribution of image intensities. For texture feature extraction a Gabor filter is simple and most extensively used approaches to extract texture feature from an original image. This filter is most popular technique for texture feature extraction. It contains filtering in spatial and frequency domain. By using bank of Gabor filter to analyze the texture, has different scales and orientations allows multichannel filtering of an image. Mathematical formula for

4.1.1.3 Edge histogram Descriptor: Shape describes surface of an object within images or particular region. Edge histogram represents 4 directional edges. The image is subdivided into 4 x 4 sub images i.e. 16 sub blocks. For each of the sub images, compute the edge densities by using 4 edge types: vertical, horizontal, 45_o and 135_o.

4.1.2 Feature Selection using Evolutionary Computation:

For image retrieval, to reduce the dimensionality and find best features from large feature set using feature selection based on two evolutionary computations i.e. Genetic Algorithm and Binary Bat Algorithm that searches optimal features corresponding to evaluation match percentage on ranking quality.

4.1.2.1 Genetic Algorithm: Genetic algorithm is compute to find solutions to search and optimization problems. Genetic algorithm is used to find optimal or best solutions to computational problem that minimizes or maximizes a particular function. They simulate biological process of natural selection and reproduction to solve for ‘fittest’ solutions. This is called ‘survival of fittest’ used for optimization problems.

4.1.2.2 Binary Bat Algorithm: Binary bat Algorithm is inspired algorithm developed by Yang, 2010. It is based on echolocation micro bats. BBA develops a discrete version of bat algorithm to solve feature selection problems and classifications. In BBA each artificial bats have a position, velocity and frequency vector. The position in BBA is either 0 or 1. The movement of bats is updating their velocity, position and frequency.

4.1.3 Clustering:

Clustering is collection of articles which are similar between same clusters while dissimilar articles belong to other cluster. In proposed system, we use k-means algorithm. We select the k-means algorithm because it manages the large number of image in cluster. In CBIR system is reducing the elapsed time of system and fast retrieval. Using k-means algorithm, the results are measure by sum of among cluster between every vector and its centroid cluster.

Chapter 5: PROPOSED WORK

Here, I am preluding our proposed method for CBIR system. The new proposed CBIR system is shown below:

The working of this system describes in step by step:

5.2.1 Preparing the features database

Step 1: Image database has color images in RGB color space.
Step 2: Calculate the color features (color moment), texture features (Gabor filter), and shape features (Edge histogram descriptor).
Step 3: These features are store in feature vector database.
Step 4: Select best features from feature database using two Evolutionary computations i.e. Genetic Algorithm, and Binary Bat Algorithm.
Step 5: Cluster the images in database using k-means Algorithm.

5.2.2 Querying

Step 1: User enter the query image in RGB color space
Step 2: Extract the features for the query image by using same techniques (color, texture and shape)
Step 3: Select best features from feature database using two evolutionary computations i.e. Genetic Algorithm, and Binary Bat Algorithm.
Step 4: Calculate the distance between the query image and the images in cluster database to find smallest distance
Step 5: the most matching images will be retrieved and then sorted in descending order.
Step 6: the first N similar images are retrieved; where N is number of the retrieve images required by user.

Here is Algorithm of two Evolutionary Computations:

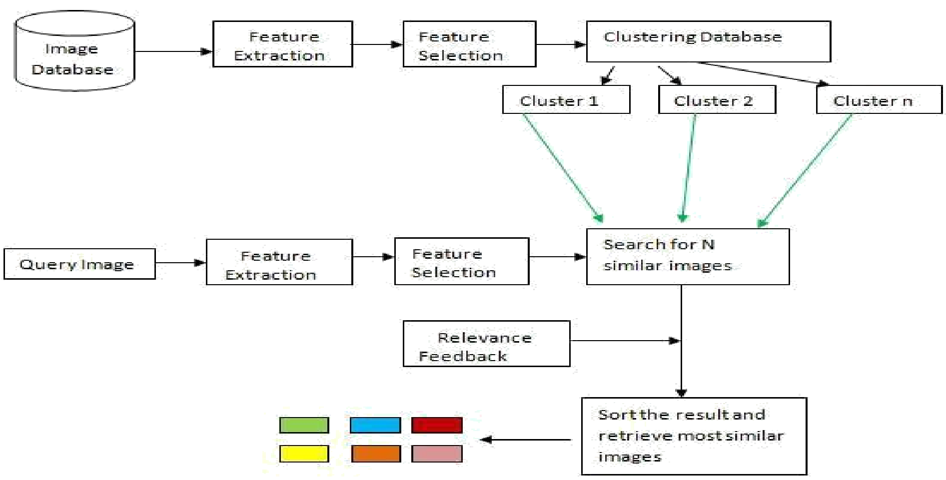
5.2.3 Genetic Algorithm

- Randomly generate an initial population

P(t) = (f1, f2,…..fn) of chromosome
Where (f1,f2,….fn) represents initial feature set

- Chromosomes creation

Select random features from initial feature set of each chromosome



Note: -Length of the chromosome is equal size for each chromosome.

- Evaluate fitness function using standard deviation of each chromosome in the current population P(t).
- Generate new population by repeating steps until new population is complete

Encode each chromosome

Crossover: - with the crossover probability Pc, if rand < Pc, select chromosomes for crossover from current population. After
that, mate the selected chromosomes randomly using single point crossover to form new offspring.
Mutation: - Mutate the new offspring with mutation probability Pm (flip ‘0’ or ‘1’) Then, Final population pool is filled up with n chromosomes.

- Repeat the process until it reaches maximum iteration.

Chapter 6: IMPLEMENTATIONS

Biometric technology such as facial recognition can quickly and accurately identify individual people and their emotional state, making it a powerful tool for ensuring security and preventing fraud.
But it can also make life more convenient by seamlessly checking weary travelers into their hotel rooms or empowering hospitals to deliver better patient care.

Facial recognition is still an emerging technology, with major US-based corporations actively pursuing it in a wide range of verticals from energy to insurance, and beyond. While it is popular from a business perspective, some observers consider the technology controversial from a civil liberties standpoint — for example, San Francisco recently banned the use of facial recognition for law enforcement purposes.
Whether allowing people to pay for goods and services with selfies or helping busy rental car drivers to get on the road in record time, we look at how several corporates are using facial recognition technology today.

1. Tech companies are developing facial recognition services for law enforcement
In the US, interest in facial recognition tech is surging, according to CB Insights' patent analysis tool — and several companies are developing the tech for law enforcement applications.
Amazon, for example, is selling its facial recognition tech — called Amazon Rekognition — to law enforcement agencies. The service promises "real-time analysis" of video streams and "face-based user verification" among other features. In addition, the company filed a patent in 2018 that explores additional layers of authentication, including asking users to perform certain actions like "smile, blink, or tilt his or her head."

Seattle-based Axon AI (fka Taser International), which is focused on developing technology for law enforcement, is reportedly looking to add facial recognition tech to its software products. The company has filed for patents incorporating facial recognition tech, which would help "identify individuals and blur out sensitive information in police footage," according to the Financial Times.
Veritone, an AI company, has developed facial recognition software known as IDentify, which compares images to those in an offender database to help match potential suspects. The system has been described as "remarkably accurate," according to Deputy Chief Julian Harvey of the Anaheim police department.

2. Automotive manufacturers tap facial recognition to control access to cars
Automotive manufacturers are testing facial recognition for driver authentication, which could help cut down on instances of car theft.
Ford and Intel have teamed up on a project called Project Mobil, in which a dashboard camera uses facial recognition to identify the primary driver of a vehicle or other authorized drivers, such as family members. One use case could be blocking the car from starting if someone other than an authorized driver sits in the driver's seat.

This in-car facial recognition approach can also be used to personalize the driving experience for each driver, calibrating the car's settings to whoever is driving — such as automatically adjusting the music volume, driver's seat position, or even vehicle speed.
Ford was also granted a patent for a keyless biometric device that authorizes drivers to operate vehicles using a variety of biometrics, including facial recognition, in 2015. This smartphone-controlled device was also envisioned as being able to issue temporary access to a car.
Chrysler took this concept a bit further with the Portal minivan, which debuted at CES in 2017. Using technology jointly developed by Panasonic Automotive and Sensory Inc, the Chrysler Portal concept car allowed a driver to sit in the seat for an initial scan and then fill out a profile on their driving preferences. From that point on, an exterior camera identified the driver as they walked to the vehicle — automatically adjusting the seat, radio, and preferred climate control settings before they entered the car. The company is hoping this technology will be showroom-ready by 2020.

3. Banks use facial recognition for authentication
Few sectors place as high a premium on security and fraud prevention as the banking industry, and US-based banks are already using facial recognition with both priorities in mind. Chase, HSBC, and USAA use Apple's FaceID to let customers securely log into their mobile banking apps, while UK-based Lloyds Bank is testing similar features using Microsoft's biometric authentication technology.

Bank of America is reportedly working on such capabilities, as well.The bank was granted a patent for an authentication system using a variety of biometrics, including facial authentication, in May 2019.
Financial institutions are also using facial recognition to streamline payments. MasterCard, for instance, has been experimenting with a feature it calls "selfie pay" since 2016, in which customers use a phone camera to approve online purchases. Amazon filed a patent for a similar payment method in 2016.

4. Beauty brands are letting customers try on makeup virtually
Beauty brands are finding facial recognition appealing as well, integrating it into the process of shopping for makeup.
Covergirl is using facial recognition in its Custom Blend App to help customers find foundation shades that complement their skin tones. While MAC is using facial recognition technology for brick-and-mortar makeup shopping, allowing customers to virtually "try on" makeup using in-store augmented reality mirrors.

5. Energy companies are leveraging facial recognition for security, payments, and driver health
Energy companies are using facial recognition for a wide range of applications, including safety, security, and payments. Chevron is apparently experimenting with facial recognition technology to detect fatigue in truck drivers — with the aim of improving safety and productivity along fuel transport routes.
Facial recognition technology is also being deployed for security purposes at plants, helping to ensure that only authorized personnel are permitted entrance to sensitive locations. One company currently pitching this solution to the energy sector is Digital Barriers.
Additionally, energy companies are using this tech to streamline the process of paying for fuel. In 2018, ExxonMobil partnered with WEX to launch DriverDash, a fuel payment app for fleet drivers that allows the use of facial recognition to authorize and document transactions.

6. Food and beverage brands are offering a personalized experience by recognizing customers
Food and beverage corporates are seeking to create a better customer experience using facial recognition technology. California fast food chain Cali Burger lets patrons quickly access their loyalty program account at a kiosk using facial recognition — allowing them to see what they've purchased previously, view personalized recommendations, and receive special discounts.
KFC has tested similar programs in China since 2017, allowing customers to pay for a meal using a facial detection payment system provided by Chinese tech giant Alibaba. BurgerFi, a Florida chain, is also using facial recognition technology to streamline ordering and remember customers' individual preferences. While candy maker Lolli & Pops is using facial recognition to personalize the customer experience for its VIP customers in a similar fashion.
Some food companies have integrated facial recognition into marketing campaigns. Frozen pizza brand DiGiorno, for example, used facial recognition for a 2017 marketing campaign where it analyzed the expressions of people at DiGiorno-themed parties in an effort to gauge people's emotional reactions to pizza.
Beverage giant Coca-Cola has used facial recognition in a number of ways across the world. Examples include rewarding customers for recycling at some of its vending machines in China, delivering personalized ads on its vending machines in Australia, and for event marketing in Israel.
McDonald's, another American giant, is currently using facial recognition in its Japanese restaurants to assess the quality of the customer service provided there, such as by analyzing whether its employees are smiling while assisting customers.

7. Healthcare firms are using facial recognition to boost patient care
Healthcare companies are exploring the use of facial recognition for a variety of purposes, including fraud prevention during the insurance claims process and helping to improve care for patients.
US-based health insurer Cigna allows customers in China to file health insurance claims which are signed using a photo, rather than a written signature, in a bid to cut down on instances of fraud.

Hospitals, meanwhile, are looking to use facial recognition to help with patient care. Use cases being tested include using facial recognition to access patient records, streamline patient registration, detect emotion and pain in patients, and even help identify certain genetic diseases. As biometric technology becomes less expensive, adoption within the healthcare sector is expected to increase across a number of areas.

8. Hotels greet guests with help from facial recognition

The hospitality industry is using facial recognition in an attempt to enhance hotel stays. In 2018, Marriott began experimenting with facial recognition to speed up the check-in process at two of its hotels in China. Should the test be successful, Marriott plans to begin rolling this technology out to its hotels throughout the world.

Facial recognition could be used to help provide a better experience for guests in other ways. For example, some industry observers speculate that concierges could use facial recognition in combination with augmented reality technology like Google Glass to automatically identify a guest before they arrive at the desk, silently call up their customer profile, and offer them a personalized greeting.

9. Insurers are pricing premiums by analyzing faces

It could soon be commonplace for insurers to leverage facial recognition technology to provide quotes for life insurance policies.

Lapetus, an insurtech startup, has developed facial recognition technology that evaluates common health conditions, such as smoking-related ailments, to aid insurers in pricing life insurance premiums. Lapetus is currently testing this product, Chronos, with a number of insurers.

US insurer Legal & General America partnered with Lapetus to launch an online tool known as SelfieQuote in 2018. Targeted at younger consumers, the tool quickly generated a life insurance quote from a submitted photo by estimating the person's age, gender, and body mass index (BMI) using facial recognition tech — though the service has since been taken offline.

In the future, insurers may seek to combine such technology with data from fitness trackers and other devices — providing companies with more ways to assess a potential customer's health.

10. Retail giants track faces to combat theft

Retailers have demonstrated interest in facial recognition for preventing shoplifting and analyzing customer sentiment, though they are not always willing to discuss whether they are currently using it in their stores.

Target and Walmart have experimented with facial recognition to combat shoplifting and fraud. Lowe's has also acknowledged that it uses facial recognition for this purpose, while Saks Fifth Avenue has reportedly used facial recognition in its Canadian stores.

Separately, Walmart is apparently developing facial recognition technology to analyze customers' moods while they are checking out at its stores. Walmart received a patent in March 2018 which described a method to track shoppers' movements around stores in a variety of ways, including via facial recognition. The retail giant could potentially use this technology to design more efficient stores or to optimize the placement of in-store displays.

Meanwhile, Facebook submitted a patent for in-store facial recognition tech that would provide retail staff with customer information drawn from social media profiles in a bid to deliver a more personalized service.

11. Travel companies are using facial recognition to bolster security

US-based airlines are deploying facial recognition to enhance security at airports across the country. Delta, JetBlue, and American Airlines are reportedly among airlines supporting security-focused facial recognition initiatives as part of a broader Department of Homeland Security push to use more facial recognition tech in US airports.

Aside from security, facial recognition is being used to help travelers board flights and rent cars. JetBlue, for example, is using facial recognition to streamline passenger boarding on some international flights, while Hertz is testing a biometrics-enabled service called Hertz Fast Lane for pre-enrolled customers — the company claims it speeds up the rental process by 75%. Hertz hopes to roll out this service to more than 40 major airports by the end of 2019.

Deployment in security services

- **Commonwealth**

The Australian Border Force and New Zealand Customs Service have set up an automated border processing system called SmartGate that uses face recognition, which compares the face of the traveller with the data in the e-passport microchip. All Canadian international airports use facial recognition as part of the Primary Inspection Kiosk program that compares a traveler face to their photo stored on the ePassport. This program first came to Vancouver International Airport in early 2017 and was rolled up to all remaining international airports in 2018–2019.

The Tocumen International Airport in Panama operates an airport-wide surveillance system using hundreds of live face recognition cameras to identify wanted individuals passing through the airport.

Police forces in the United Kingdom have been trialling live facial recognition technology at public events since 2015. However, a recent report and investigation by Big Brother Watch found that these systems were up to 98% inaccurate.

In May 2017, a man was arrested using an automatic facial recognition (AFR) system mounted on a van operated by the South Wales Police. Ars Technica reported that "this appears to be the first time [AFR] has led to an arrest".

Live facial recognition has been trialled since 2016 in the streets of London. It will be used on a regular basis from Metropolitan Police from beginning of 2020.

United States

The U.S. Department of State operates one of the largest face recognition systems in the world with a database of 117 million American adults, with photos typically drawn from driver's license photos.Although it is still far from completion, it is being put to use in certain cities to give clues as to who was in the photo. The FBI uses the photos as an investigative tool, not for positive identification.As of 2016, facial recognition was being used to identify people in photos taken by police in San Diego and Los Angeles (not on real-time video, and only against booking photos) and use was planned in West Virginia and Dallas.

In recent years Maryland has used face recognition by comparing people's faces to their driver's license photos. The system drew controversy when it was used in Baltimore to arrest unruly protesters after the death of Freddie Gray in police custody. Many other states are using or developing a similar system however some states have laws prohibiting its use.

The FBI has also instituted its Next Generation Identification program to include face recognition, as well as more traditional biometrics like fingerprints and iris scans, which can pull from both criminal and civil databases. The federal General Accountability Office criticized the FBI for not addressing various concerns related to privacy and accuracy.

In 2019, researchers reported that Immigration and Customs Enforcement uses facial recognition software against state driver's license databases, including for some states that provide licenses to undocumented immigrants.

China

As of late 2017, China has deployed facial recognition and artificial intelligence technology in Xinjiang. Reporters visiting the region found surveillance cameras installed every hundred meters or so in several cities, as well as facial recognition checkpoints at areas like gas stations, shopping centers, and mosque entrances.
In 2020, China provided a grant to develop facial recognition technology to identify people wearing surgical or dust masks by matching solely to eyes and foreheads.

The Netherlands

Like China, but a year earlier, The Netherlands has deployed facial recognition and artificial intelligence technology since 2016. The database of the Dutch police currently contains over 2.2 million pictures of 1.3 million Dutch citizens. This accounts for about 8% of the population. Hundreds of cameras have been deployed in the city of Amsterdam alone.

South Africa

In South Africa, in 2016, the city of Johannesburg announced it was rolling out smart CCTV cameras complete with automatic number plate recognition and facial recognition.

Indian Startups working in this direction:

Over the past few years, with so many crimes and unfortunate events taking place, the need for surveillance has skyrocketed all over the globe. And this rising need is driving companies as well as government organisations across the world to come up with innovations in facial recognition.

The Indian tech community is also extensively working on the facial recognition domain to build top-notch products and services. In this article, we list five startups from India that are going all out to fill the void in the domain with quality facial recognition offerings.

(This list is in alphabetical order.)

- **AIndra Labs**

Founded by Abhishek Mishra, Abdulla Hisham and Rito Bhaumik in 2016, AIndra Labs is one of the top 10 AI startups in India. The company uses computer vision and ML and is specialised in processing images and videos captured from real-life scenarios using its Visual Analytics Platform.

The company also has an AI-powered face recognition solution to mark the attendance of the employees or students of the organisation. Basically, the face recognition system stores photographs and details on each student of a class in a server, and to take attendance of the class, the teacher just need to click some pictures of the classroom. The system digs into the server matches the faces on the photograph with the data previously store and suggests who is present and absent.

- **FaceX**

Founded in 2018 by Safeer Usman in Bangalore India, FaceX is a small team that are doing big in the facial recognition field. The company's technology employs state-of-the-art tracking technology to detect people even under low illumination and varied poses. That is not all, it also detects people at far distances, even when the face is pixelated very badly to the human eye. Further, it recognises faces with an accuracy rate of 94%.

This new-born startup in a short span of time has achieved some real success. Today, the company works with a significant number of clients — from entrepreneurs to big companies. It also works with 100 developers that work with facial recognition applications.

- **ParallelDots**

Founded by a trio Angam Parashar, Ankit Narayan Singh, and Muktabh Mayank, ParellelDots claims to be one of the best applied AI research groups in the world. Speaking about facial recognition, the companies image recognition API finds the label(s) (names) of objects in the image along with its probability score. And its image recognition can identify 6,000 commonly occurring everyday objects from an image.

Further, it can also detect human emotions from facial expressions. This API by ParellelDots can be used to monitor emotions associated with visual content shared on social media or photo-sharing apps or build interactive video chat applications.

- **ShepHertz**

Founded by Siddhartha Chandurkar, ShepHertz is a Gurugram-based startup that not only provides APIs to build Omni-Channel Apps but also provides Actionable Big Data solution. Also, they have a comprehensive set of AI and ML and they have started working on facial recognition as well.

After a horrifying incident in Ryan International School, Gurugram, ShepHertz, set out to do something about the security and surveillance in schools. And having worked with some of the big enterprises, processing close over 115 billion API calls, and sheer focus on AI, the company has developed a software solution called SchoolProtect. It is basically a facial recognition solution that can be used by schools and can be deployed in their existing surveillance infrastructure.

- **Staqu**

Based in Gurugram, Staqu is an AI-focused company that with a technology stack of advanced image and video analysis tools, language and text-independent speaker identification engine, speech recognition, facial recognition and text processing APIs.

Staqu's AI-based human efface detection (ABHED) offers a smart glass that has an inbuilt camera that takes real-time human features as input to provide a match for criminal record in seconds. Another product is a violence detection system that analyses CCTV footage to identify and report violence in real-time. And last, it also provides facial recognition system that utilises CCTV feeds to recognise faces through live camera feed, possible in a moment.

***Chapter 7*: INDUSTRY APPLICATIONS AND ADOPTION PITFALLS**

Each time you recognize someone's face, you're using an internal form of facial recognition. In a matter of milliseconds, your mind breaks down the parts of their face, puts them back together, and matches the sum with those faces already stored in your memory. When the process works seamlessly, you don't even realize it's happening.

While you may not have given much thought to how your brain distinguishes one face from another, the behind-the-scenes process is fascinating and serves as the foundation for modern facial recognition apps. Though still considered an emerging technology, facial recognition is already being used in a number of applications ranging from social media to security. As more businesses consider applying this technology to their own organizations, computer vision consulting becomes essential as there are many roadblocks on the way to adoption.

How Businesses Are Currently Using Facial Recognition Apps

The applications utilizing facial recognition are widespread. You've probably already interacted with this technology, perhaps without even realizing it:

Security. The American drugstore chain Rite Aid Corp uses facial recognition in over 200 stores across the country to detect theft and alert staff about people that were previously engaged in criminal activities. In case of a potential threat, security agents are notified via their smartphones.

Marketing. India-based FaceX provides a state-of-the-art facial recognition technology that helps retailers measure the appeal of certain products based on customers' emotions and heat maps, in order to devise targeted advertisements based on gender and age.

Authentication. Android has a facial recognition app called Smart Lock, which allows smartphone owners to unlock their phones by holding it up to their faces. Apart from that, Face ID is the secure facial recognition-based login system developed by Apple for iOS devices.

Payments. Alibaba, the Chinese e-commerce powerhouse, has integrated facial recognition software in its payment service, Alipay. Chinese customers can now pay by just showing their face to computer-vision enabled devices called Dragonfly 2. The system is currently deployed in more than 300 cities across China.

Photo tagging. One of the earliest adopters of the facial recognition technology, Facebook first started using it back in 2011. Any time a user uploads a photo, the company's facial recognition system systematically compares all of the faces in it with those of the user's friends. If a match is found, the interface suggests that the user tag their photo with the friend's name.

The Potential Pitfalls

While most people agree that facial recognition software has the power to revolutionize how businesses interact with consumers, there is also little doubt that in order for this technology to be successfully adopted on a larger scale, the potential pitfalls should also be considered and, ideally, circumvented.

Checks and Balances

Facial recognition technology implies access to sensitive personal information, and the potential for misuse is very real. This applies to the business realm as well, which is why organizations, big and small, need to make sure that they have the appropriate checks and balances in place before implementing facial recognition as part of their product or service offerings.

User Rights

Every time someone's face is scanned by a facial recognition app, the results of that scan, specifically the mathematical formula that distinguishes that person from others, is stored somewhere in a database. Depending on who owns this database, any number of third parties may have access to it. Informing customers of how and when their information may be used (as per the GDPR) and obtaining their consent for such usage can go a long way towards establishing trust, in addition to preventing legal issues down the road.

Fallibility
Companies need to recognize that no technology, including facial recognition, is infallible. Likewise, since facial recognition algorithms are trained using data collected by humans, they are also not immune to bias. In fact, there have been several reported instances of facial recognition systems incorrectly identifying the gender of people with darker skin tones or even mistaking them for criminals.
Facial recognition algorithms are only as good as the data they are trained on. The above scenarios occurred due to a lack of photos representing a diverse array of people along with the overrepresentation of black people on mugshots. Companies can reduce these issues by making sure that facial recognition programs are properly trained with a sufficient and diverse amount of data.
Crime
With each new wave of technology comes a new type of crime. The same facial recognition tools that allow the police to track criminals and find missing people can be used to perpetrate crimes like stalking, theft, and fraud. Industrious criminals could access facial recognition data, either publicly or by hacking a private database, to track people without their permission. They would know when someone was at home, at work, or out of the country altogether, which makes theft significantly easier.
In addition, those with dubious intentions could also pretend to know people whose facial recognition data they have accessed, in the hope of gaining sensitive personal information that could be used to commit fraud or even identity theft. In sum, the degree of damage that criminals can inflict with the aid of facial recognition software is substantial. Knowing this can help companies prepare for this eventuality and provide them with a framework of information that could inform cybersecurity and facial data protection measures.

Even if you are a celebrity of some kind and have a bunch of absolute twins who know where you live, a well-developed Face Recognition access control system can, virtually, eliminate the odds of unwarranted access to your personal device, dwelling, car, or office. No, none of your snapshots of the Web can become a security hazard in this case either.

Surprisingly, some of the more sophisticated Face Recognition algorithms are able to identify even someone who has undergone plastic surgery to change their appearance.

Attendance Tracking and Control: Finally an Upper Hand
Face Recognition can become a true scourge for those, who like to play truant regardless of the place they are supposed to attend. It becomes possible to efficiently track attendance at individual teaching events that involve hundreds of attendees.
Moreover, in addition to curbing truancy, Facial Recognition technology is, also, capable of ensuring that order is maintained wherever your teaching event is taking place.
For example, just picture your mobile device has a face recognition app installed on it. This app allows you to identify a misbehaving attendee (and soundly reprimand them later) by just pointing your mobile phone in their direction. Do you think this would help maintain order? We bet it would.

Marketing: A New Source of Direct Insights
Marketing is one of the business domains being disrupted by Artificial Intelligence the most. And it is no longer only about tracking user behavior in an eCommerce app and displaying relevant ads to them later, or text-mining the Web for insights into your target audience's preferences. Facial Recognition technology has, recently, taken the process to an entirely new level. It makes it easier not only to sell but also to buy in those instances when the buyer is poised for choice or is just not aware of all the features of several similar products.
Talking of examples, according to a.list, the well-known tour provider Expedia has now partnered with a Hawaii-based tourist agency to offer Face Recognition-recommended tour options. The Facial Recognition solution, used by the company, determines which of the Hawaii-based tourist activities, presented to the viewer on the Expedia website, resonates with them most positively.

Banking: At Long Last, What Can Be Referred to as Reliable Authorization

Battling fraud in Banking has, probably, never ceased ever since the trade was in its infancy.

Nowadays, multi-factor authentication solutions, which provide two- or, even, three-step authentication, are used to reduce the amount of the fraud that plagues banking institutions around the globe. These solutions, generally, succeed, but may sometimes affect the customer experience unfavorably.

Besides, in some contexts, for example, in the case of ATM skimming, multi-factor authentication is of no use.

As you will have, probably, guessed, a truly dependable solution can be provided by Face Recognition.

Public Security: The Arrival of a New, Powerful Tool

Some of the applications of Face Recognition are not only useful or immensely important. Their significance is also rapidly on the rise.

The above is, especially, true for an array of overlapping security-related applications of the Face Recognition technology. These applications have been rendered of paramount importance by the global need for better public security.

One of such applications is the use of Face Recognition solutions by customs offices to keep unwanted visitors out of a country and control entry into and departure from it otherwise. This is what has, actually, been done by the US Customs and Border Protection for some time now: US Customs and Border Protection Officers use a Facial Recognition technology to verify whether someone, producing a US passport, and the male or female, whose passport they are carrying, are, actually, the same person.

Similarly, provided corresponding international databases are put in place, it may shortly become possible to identify those wanted or considered to be a public menace regardless of the ID they carry, as well as to monitor their cross-border movements.

The security-related applications of Facial Recognition can be many and extremely wide-ranging.

Key Market Trends

Retail and E-commerce is Expected to Hold Significant Share

- While Facial recognition technology did not absorb a huge demand from the retail industry initially, it provided the adequate potential for the technology over the past few years.

- The advancement in three technical fields, like Neural Network, Big Data, and Graphical Processing Unit (GPU) has played a significant role in the widespread use of Facial Recognition Technology in the sector. For instance, apparel retailers are leveraging the technology to deliver customized products to the customers visiting their stores.

- Vero Modaand Jack & Jones, the brands owned by Danish fashion retailer, opened smart stores powered with facial recognition technology, in Shenzhen and Guangzhou, China. The technology, provided by Tencent's YouTuLab, enables making payment without using any cash or card and allows to pass on personalized recommendations to the customers.

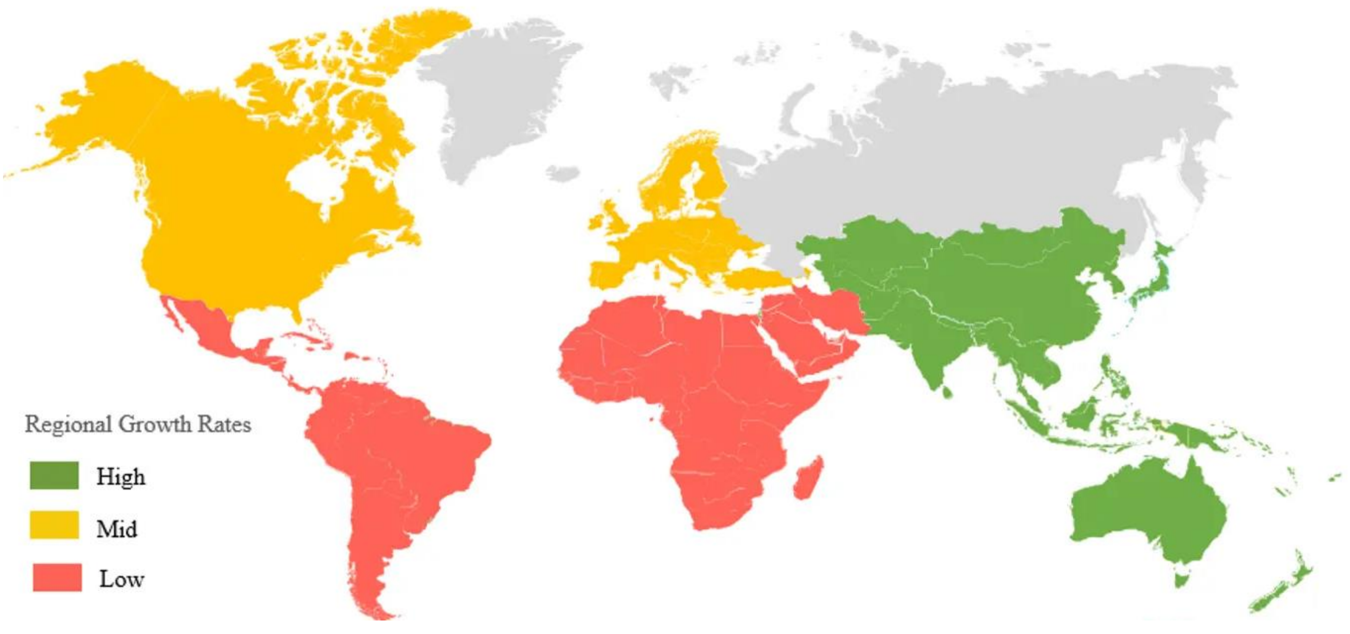
- **FaceX, a company based out of India**, is a provider of facial recognition technology that is helping the retail sector with features, like a facial landmark, facial detection, face recognition, face tracking, and spoof detection. In addition to these, in a bid to pass on personalized touch to the customers, the technology also greets the customers upon entering the retail store.

- Likewise, Ruti (India), a brand focused on women apparel (35 years and older), deployed facial recognition technology in its stores to offer personalized recommendations based on its preferences, like sizes, likes, and dislikes. Upon entering the store, the customers' faces are scanned. The photos (including the items related to purchase if one made) from the installed cameras are stored in the retailer's CRM system, on customers' approval. Thereby, it can identify customers’ profiles and repeat customers, traces their shopping history within seconds.

Asia-Pacific is Expected to Register Fastest Growth

- The Asia-Pacific is the most prominent region for the adoption of facial recognition, owing to factors, such as technological development, rising in infrastructure growth, and the increasing application in numerous areas. Massive industrialization and the growing consumer electronics industry in the region highlight the exciting opportunities for the players in the market and the scope for significant growth.
- Since long, China has used facial recognition technology and built a giant database for facial identification of its population of more than 1.3 billion. Besides, the country has had several partnerships within the country that have helped maintain China's domination over the global physical security equipment market.
- Further, the country has deployed facial recognition glasses for the country's police force, to spot citizens and tourists, and use real-time ID authentication to primarily fight crimes during time of celebrations.
- Also, the country is embracing facial authenticated payments. AliPay, China's biggest payment app, started a trial for the smile-to-pay feature at a branch of KFC in Southern China, which uses facial recognition to identify the customer and automatically charges them through the app.
- With increasing urban population and increased purchasing power, Asia-Pacific is one of the largest markets for consumer biometrics. Increasing mobile transactions for banking in countries, such as India and China, coupled with their governments' initiatives, are expected to be the major drivers for the facial recognition market in the region.

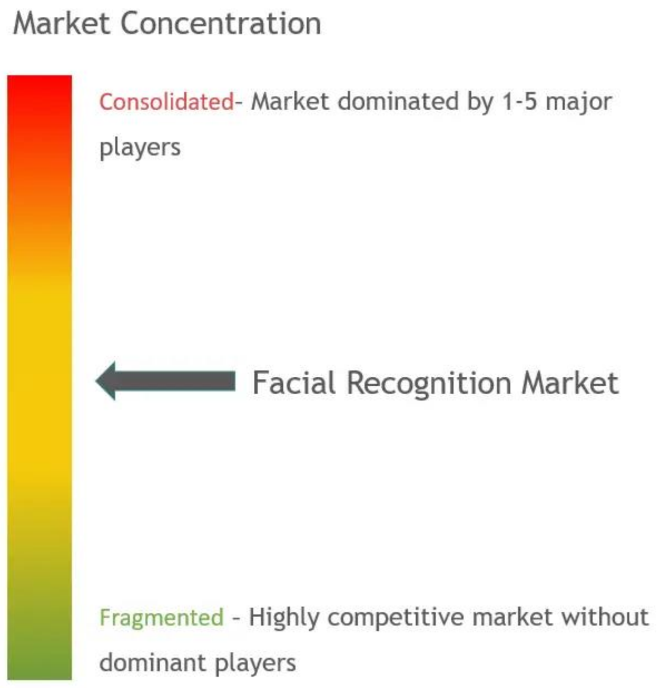
Facial Recognition Market - Growth Rate by Region (2021 - 2026)



Competitive Landscape

The competitive rivalry in the facial recognition market is moderately fragmented, despite the presence of significant players operating in the market, such as NEC Corporation, Gemalto NV, and Panasonic Corporation, etc. With the number of startups growing at a substantial rate in the study market, the market is expected to witness a highly competitive scenario shortly.

- June 2020 - Panasonic Corporation of North America and PopID, a Cali Group company, partnered to bring facial recognition ordering and payment processes to both the restaurant and retail industries. Under the terms of the agreement between the parties, PopID and PopPay will be fully integrated into the Panasonic ClearConnect Kiosk application, and Panasonic will have preferential rights in the kiosk market.



Major Players

1. NEC Corporation
2. Aware Inc.
3. Animetrics Inc.
4. Panasonic Corporation
5. Thales Group

Recent Developments

- May 2020 - NEC Corporation launched NeoFace Thermal Express to provide touchless screening. The new offering combines elevated body temperature (EBT) detection and personal protective equipment, such as face masks, and NeoFace biometrics on a scalable and modular platform with video and thermal analytics.
- January 2020 - FaceFirst announced the availability of its face recognition Software Development Kit (SDK). This enables developers of security and identity verification products to incorporate advanced facial recognition and other video analytics into their solutions with just a few lines of code

Chapter 8: ADVANTAGES AND DISADVANTAGES

Compared to other biometric systems

One key advantage of a facial recognition system that it is able to person mass identification as it does not require the cooperation of the test subject to work. Properly designed systems installed in airports, multiplexes, and other public places can identify individuals among the crowd, without passers-by even being aware of the system.

However, as compared to other biometric techniques, face recognition may not be most reliable and efficient. Quality measures are very important in facial recognition systems as large degrees of variations are possible in face images. Factors such as illumination, expression, pose and noise during face capture can affect the performance of facial recognition systems. Among all biometric systems, facial recognition has the highest false acceptance and rejection rates, thus questions have been raised on the effectiveness of face recognition software in cases of railway and airport security.

Weaknesses

Ralph Gross, a researcher at the Carnegie Mellon Robotics Institute in 2008, describes one obstacle related to the viewing angle of the face: "Face recognition has been getting pretty good at full frontal faces and 20 degrees off, but as soon as you go towards profile, there've been problems."Besides the pose variations, low-resolution face images are also very hard to recognize. This is one of the main obstacles of face recognition in surveillance systems.

Face recognition is less effective if facial expressions vary. A big smile can render the system less effective. For instance: Canada, in 2009, allowed only neutral facial expressions in passport photos.

There is also inconstancy in the datasets used by researchers. Researchers may use anywhere from several subjects to scores of subjects and a few hundred images to thousands of images. It is important for researchers to make available the datasets they used to each other, or have at least a standard dataset.

Data privacy is the main concern when it comes to storing biometrics data in companies. Data stores about face or biometrics can be accessed by the third party if not stored properly or hacked. In the Techworld, Parris adds (2017), “Hackers will already be looking to replicate people's faces to trick facial recognition systems, but the technology has proved harder to hack than fingerprint or voice recognition technology in the past.”

Ineffectiveness

Critics of the technology complain that the London Borough of Newham scheme has, as of 2004, never recognized a single criminal, despite several criminals in the system's database living in the Borough and the system has been running for several years. "Not once, as far as the police know, has Newham's automatic face recognition system spotted a live target." This information seems to conflict with claims that the system was credited with a 34% reduction in crime (hence why it was rolled out to Birmingham also).However it can be explained by the notion that when the public is regularly told that they are under constant video surveillance with advanced face recognition technology, this fear alone can reduce the crime rate, whether the face recognition system technically works or does not. This has been the basis for several other face recognition based security systems, where the technology itself does not work particularly well but the user's perception of the technology does.

An experiment in 2002 by the local police department in Tampa, Florida, had similarly disappointing results.

A system at Boston's Logan Airport was shut down in 2003 after failing to make any matches during a two-year test period.

In 2014, Facebook stated that in a standardized two-option facial recognition test, its online system scored 97.25% accuracy, compared to the human benchmark of 97.5%.

In 2018, a report by the civil liberties and rights campaigning organisation Big Brother Watch revealed that two UK police forces, South Wales Police and the Metropolitan Police, were using live facial recognition at public events and in public spaces, in September 2019, South Wales Police use of facial recognition was ruled lawful.

Systems are often advertised as having accuracy near 100%; this is misleading as the studies often use much smaller sample sizes than would be necessary for large scale applications. Because facial recognition is not completely accurate, it creates a list of potential matches. A human operator must then look through these potential matches and studies show the operators pick the correct match out of the list only about half the time. This causes the issue of targeting the wrong suspect.

Chapter 9: CONCLUSIONS

In this section, we'll give summaries on face detection and face recognition techniques during the past twenty year as well as popular face data set for experiments and their characteristics.

Method	Category	Characteristics
Hierarchical knowledge-based	Knowledge-based	Coarse-to-fine procedure
Horizontal / vertical projection	Knowledge-based	
Face Detection Using Color Information	Feature-based	Combining skin-color detection, face shape verification, and facial feature configuration for detection
Face detection based on ra ndom labelled graph matching graph matching [11]	Feature-based	Combining simple features with statistical learning and estimation
Active appearance model	Template matching	Learning facial shape and appearance variation by data
Example-based learning	Appearance-based	Learning the face and non-face distribution by mixture of Gaussian
Haar features with Ad boost	Appearance-based	Ad boost for speed-up
Generative models	Part-based	Unsupervised extracting important facial features, and learning the relation among parts and discrimination be-
Component-based with SVM	Part-based	Learning global and local SVM for detection

Table 1: The summary of face detection techniques

Method	Category	Characteristics
PCA	Holistic-based	PCA for learning Eigen faces, unsupervised
LDA	Holistic-based	LDA for learning fisher faces, supervised
2D-PCA	Holistic-based	2D-PCA for better statistical properties
ICA	Holistic-based	ICA for catch facial independent components, two architectures are proposed
Laplacian faces	Holistic-based	Nonlinear dimension reduction for finding bases, LPP
Evolutionary pursuit	Holistic-based	Using the genetic algorithm for finding the best projection bases based on generalization error
Kernel PCA And Kernel LDA	Holistic-based	Mapping the image into higher-dimensional space by the kernel function, and exploit the PCA and LDA bases there
Sparse representation	Holistic-based	Using L1 minimization and over-complete dictionary for finding sparse representation
Gabor and dynamic link architecture	Feature-based	Gabor features extracted at facial feature locations, while performing one-by-one matching
Gabor and elastic bunch graph matching	Feature-based	Gabor features extracted at facial feature locations, and obtaining the robust representation by the FBG matching.

LBP	Feature-based	Local binary patterns are introduced
LTP	Feature-based	Binary into ternary
AAM	Template matching	AAM parameters for classification learning
Component-based	Part-based	Comparing global and component representation, while a
SIFT	Part-based	Using SIFT feature with spatial constraints to compare faces

Table 2: The summary of face recognition techniques

Name	RGB/gray	Image size	# people	Pictures/person	Conditions	Available
AR Face Database*	RGB	576x768	126	26	i, e, o, t	Yes
Richard's MIT	RGB	480x640	154	6	p, o	Yes
CVL	RGB	640x480	114	7	p, e	Yes
The Yale Face Database B*	Gray	640x480	10	576	p, i	Yes
The Yale Face Database*	Gray	320x243	15	11	i, e	Yes
PIE*	RGB	640x486	68	~608	p ,i, e	Yes
The UMIST Face Database	Gray	220x220	20	19-36	p	Yes
Olivetti Att-ORL*	Gray	92x112	40	10		Yes
JAFFE	Gray	256x256	10	7	e	Yes
The Human Scan	Gray	384x286	23	~66		Yes
XM2VTSDB	RGB	576x720	295		p	With pay
FERET*	RGB/gray	256x384	30000		p, i, e, i/o, t	Yes

Table 3: The summary of popular databases used for detection and recognition tasks

The (*) points out most used databases. Image variations are indicated by (i) illumination, (p) pose, (e) expression, (o) occlusion, (i/o) indoor/outdoor conditions and (t) time delay.

Closing Thoughts

Developments in the field of facial recognition are occurring at a rapid pace. While the widespread application of this technology holds much promise, it also needs to be handled with as much care. Businesses that want to use facial recognition apps need to understand this and approach their strategies with care and consideration. Those that successfully manage to do this are sure to reap the benefits of facial recognition.

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ANNEXURE:

Facial Detection and Recognition: A Detailed Survey

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Abstract : Face recognition has been one of the most interesting and important research fields in the past two decades. The reasons come from the need of automatic recognitions and surveillance systems, the interest in human visual system on face recognition, and the design of human-computer interface, etc. These researches involve knowledge and researchers from disciplines such as neuroscience, psychology, computer vision, pattern recognition, image processing, and machine learning, etc. A bunch of papers have been published to overcome difference factors (such as illumination, expression, scale, pose, ……) and achieve better recognition rate, while there is still no robust technique against uncontrolled practical cases which may involve kinds of factors simultaneously. In this report, we'll go through general ideas and structures of recognition, important issues and factors of human faces, critical techniques and algorithms, and finally give a conclusion.

1. INTRODUCTION

In this report, we focus on image-based face recognition. Given a picture taken from a digital camera, we'd like to know if there is any person inside, where his/her face locates at, and who he/she is. Towards this goal, we generally separate the face recognition procedure into three steps: Face Detection, Feature Extraction, and Face Recognition (shown at fig.1 below).

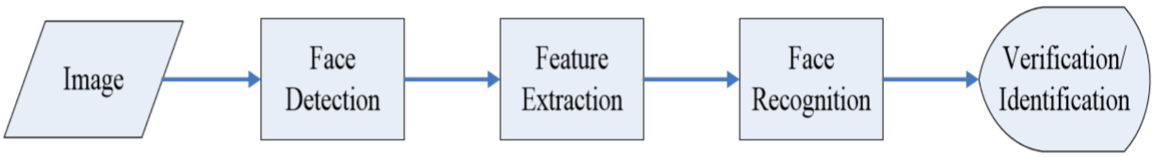

Figure1: Configuration of a general face recognition structure

Face Detection:
The main function of this step is to determine (i) whether human faces appear in a given image, and (ii) where these faces are located at. The expected outputs of this step are patches containing each face in the input image. In order to make further face recognition system more robust and easier to design, face alignment is performed to justify the scales and orientations of these patches. Besides serving as the pre-processing for face recognition, face detection could be used for region-of-interest detection, retargeting, video and image classification, etc.

Feature Extraction:
After the face detection step, human-face patches are extracted from images. Directly using these patches for face recognition have some disadvantages, first, each patch usually contains over 1000 pixels, which are too large to build a robust recognition system1. Second, face patches may be taken from different camera alignments, with different face expressions, illuminations, and may suffer from occlusion and clutter. To overcome these drawbacks, feature extractions are performed to do information packing, dimension reduction, salience extraction, and noise cleaning. After this step, a face patch is usually transformed into a vector with fixed dimension or a set of fiducial points and their corresponding locations. In some literatures, feature extraction is either included in face detection or face recognition.

Face Recognition:
After formulizing the representation of each face, the last step is to recognize the identities of these faces. In order to achieve automatic recognition, a face database is required to build. For each person, several images are taken and their features are extracted and stored in the database. Then when an input face image comes in, we perform face detection and feature extraction, and compare its feature to each face class stored in the database. There have been many researches and algorithms proposed to deal with this classification problem, and we'll discuss them in later sections. There are two general applications of face recognition, one is called identification and another one is called verification. Face identification means given a face image, we want the

system to tell who he / she is or the most probable identification; while in face verification, given a face image and a guess of the identification, we want the system to tell true or false about the guess.

2. FUNDAMENTAL OF PATTERN RECOGNITION

Before going into details of techniques and algorithms of face recognition, we'd like to make a digression here to talk about pattern recognition. The discipline, pattern recognition, includes all cases of recognition tasks such as speech recognition, object recognition, data analysis, and face recognition, etc. In this section, we won't discuss those specific applications, but introduce the basic structure, general ideas and general concepts behind them. The general structure of pattern recognition is shown in figure below. In order to generate a system for recognition, we always need data sets for building categories and compare similarities between the test data and each category. A test data is usually called a "query" in image retrieval literatures, and we will use this term throughout this report. From figure, we can easily notice the symmetric structure. Starting from the data sets side, we first perform dimension reduction2 on the stored raw data. The methods of dimension reduction can be categorized into data-driven methods and domain-knowledge methods, which will be discussed later. After dimension reduction, each raw data in the data sets is transformed into a set of features, and the classifier is mainly trained on these feature representations. When a query comes in, we perform the same dimension reduction procedure on it and enter its features into the trained classifier. The output of the classifier will be the optimal class (sometimes with the classification accuracy) label or a rejection note (return to manual classification).

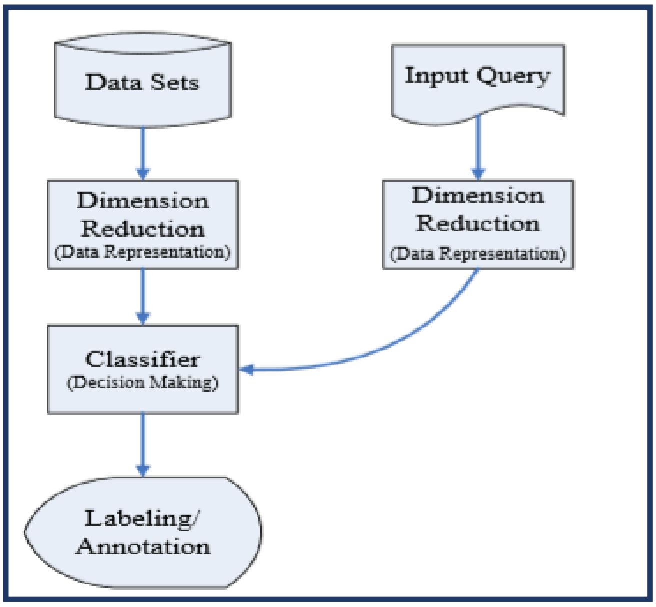

Figure2: General structure of a pattern recognition system

3. ISSUES AND FACTORS OF HUMAN FACES

When focusing on a specific application, besides building the general structure of pattern recognition system, we also need to consider the intrinsic properties of the domain-specific data. For example, to analyze music or speech, we may first transform the input signal into frequency domain or MFCC (Mel-frequency cepstral coefficients) because features represented in these domains have been proved to better capture human auditory perception. In this section, we'll talk about the domain-knowledge of human faces, factors that result in face-appearance variations in images, and finally list important issues to be considered when designing a face recognition system.

Aspects from psychophysics and neuroscience

There are several researches in psychophysics and neuroscience studying about how we human performs recognition processes, and many of them have direct relevance to engineers interested in designing algorithms or systems for machine recognition of faces. In this subsection, we briefly review several interesting aspects. The first argument in these disciplines is that whether face recognition a dedicated process against other object recognition tasks. Evidences that faces are more easily remembered by humans than other objects when presented in an upright orientation and prosopagnosia patients can recognize faces from other objects but have difficulty in identifying the face support the viewpoint of face recognition as a dedicated process. While recently, some findings in human neuropsychology and neuroimaging suggest that face recognition may not be unique.

Holistic-based or feature-based

This is another interesting argument in psychophysics / neuroscience as well as in algorithm design. The holistic-based viewpoint claims that human recognize faces by the global appearances, while the feature-based viewpoint believes that important features such as eyes, noses, and mouths play dominant roles in identifying and remembering a person.

Thatcher Illusion

The Thatcher illusion is an excellent example showing how the face alignment affects human recognition of faces. In the illusion shown in the figure below, eyes and mouth of an expressing face are excised and inverted, and the result looks grotesque in an upright face. However, when shown inverted, the face looks fairly normal in appearance, and the inversion of the internal features is not readily noticed.

Factors of human appearance variations

There are several factors that result in difficulties of face detection and face recognition. Except the possible low quality driven from the image acquisition system, we focus on the angle of human faces taken by the camera and the environment of photo acquisition. There are generally six factors we need to concern: (i) illumination, (ii) face pose, (iii) face expression, (iv) RST (rotation, scale, and translation) variation, (v) clutter background, and (vi) occlusion. Table 1 lists the details of each factor.

Illumination	The illumination variation has been widely discussed in many face detection and recognition researches. This variation is caused by various lighting environments and is mentioned to have larger appearance difference than the difference caused by different identities. The example of illumination changes on images of the same person, and it's obviously that under some illumination conditions, we can neither assure the identification nor accurately point out the positions of facial features.
Pose	The pose variation results from different angles and locations during the image acquisition process. This variation changes the spatial relations among facial features and causes serious distortion on the traditional appearance-based face recognition algorithms such as Eigen faces and fisher faces.
Expression	Human uses different facial expressions to express their feelings or tempers. The expression variation results in not only the spatial relation change, but also the facial-feature shape change.
RST variation	The RST (rotation, scaling, and translation) variation is also caused by the variation in image acquisition process. It results in difficulties both in face detection and recognition, and may require exhaustive searching in the detection process over all possible RST parameters.
Cluttering	In addition to the above four variations which result in changes in facial appearances, we also need to consider the influence of environments and backgrounds around people in images. The cluttering background affects the accuracy of face detection, and face patches including this background also diminish the performance of face recognition algorithms.
Occlusion	The occlusion is possibly the most difficult problem in face recognition and face detection. It means that some parts of human faces are unobserved, especially the facial features.

Table 1: The list and description of the six general factors

4. Face detection

Knowledge-based methods

These rule-based methods encode human knowledge of what constitutes a typical face. Usually, the rules capture the relationships between facial features. These methods are designed mainly for face localization, which aims to determine the image position of a single face. In this subsection, we introduce two examples based on hierarchical knowledge-based method and vertical / horizontal projection.

Hierarchical knowledge-based method

This method is composed of the multi-resolution hierarchy of images and specific rules defined at each image level [4]. The hierarchy is built by image sub-sampling. The face detection procedure starts from the highest layer in the hierarchy (with the lowest resolution) and extracts possible face candidates based on the general look of faces. Then the middle and bottom layers carry rule of more details such as the alignment of facial features and verify each face candidate. This method suffers from many factors described in Section 3 especially the RST variation and doesn't achieve high detection rate (50 true positives in 60 test images), while the coarse-to-fine strategy does reduce the required computation and is widely adopted by later algorithms.

Horizontal / vertical projection

This method uses the fairly simple image processing technique, the horizontal and vertical projection [6]. Based on the observations that human eyes and mouths have lower intensity than other parts of faces, these two projections are performed on the test image and local minimums are detected as facial feature candidates which together constitute a face candidate. Finally, each face candidate is validated by further detection rules such as eyebrow and nostrils.

Feature invariant approaches

These algorithms aim to find structural features that exist even when the pose, viewpoint, or lighting conditions vary, and then use these to locate faces. These methods are designed mainly for face localization. To distinguish from the knowledge-based methods, the feature invariant approaches start at feature extraction process and face candidates finding, and later verify each candidate by spatial relations among these features, while the knowledge-based methods usually exploit information of the whole image and are sensitive to complicated backgrounds.

Face Detection Using Color Information

In this work, Hsu et al [7] proposed to combine several features for face detection. They used color information for skin-color detection to extract candidate face regions. In order to deal with different illumination conditions, they extracted the 5% brightest pixels and used their mean color for lighting compensation. After skin-color detection and skin-region segmentation, they proposed to detect invariant facial features for region verification. Human eyes and mouths are selected as the most significant features of faces and two detection schemes are designed based on chrominance contrast and morphological operations, which are called "eyes map" and "mouth map". Finally, we form the triangle between two eyes and a mouth and verify it based on (i) luminance variations and average gradient orientations of eye and mouth blobs, (ii) geometry and orientation of the triangle, and (iii) the presence of a face boundary around the triangle. The regions pass the verification are denoted as faces and the Hough transform are performed to extract the best-fitting ellipse to extract each face. This work gives a good example of how to combine several different techniques together in a cascade fashion. The lighting compensation process doesn't have a solid background, but it introduces the idea that despite modelling all kinds of illumination conditions based on complicated probability or classifier models, we can design an illumination-adaptive model which modifies its detection threshold based on the illumination and chrominance properties of the present image. The eyes map and the mouth map show great performance with fairly simple operations and in our recent work we also adopt their framework and try to design more robust maps.

Face detection based on random labelled graph matching

Leung et al. developed a probabilistic method to locate a face in a cluttered scene based on local feature detectors and random graph matching [8]. Their motivation is to formulate the face localization problem as a search problem in which the goal is to find the arrangement of certain features that is most likely to be a face pattern. In the initial step, a set of local feature detectors is applied to the image to identify candidate locations for facial features, such as eyes, nose, and nostrils, since the feature detectors are not perfectly reliable, the spatial arrangement of the features must also be used for localize the face. The facial feature detectors are built by the multi-orientation and multi-scale Gaussian derivative filters, where we select some characteristic facial features (two eyes, two nostrils, and nose/lip junction) and generate a prototype filter response for each of them. The same filter operation is applied to the input image and we compare the response with the prototype responses to detect possible facial features. To enhance the reliability of these detectors, the multivariate-Gaussian distribution is used to represent the distribution of the mutual distances among each facial feature, and this distribution is estimated by a set of training arrangements. The facial feature detectors averagely find 10-20 candidate locations for each facial feature, and the brute-force matching for each possible facial feature arrangement is computationally very demanding. To solve this problem, the authors proposed the idea of controlled search. They set a higher threshold for strong facial feature detection, and each pair of these strong features is selected to estimate the locations of other three facial features using a statistical model of mutual distances. Furthermore, the covariance of the estimates can be computed. Thus, the expected feature locations are estimated with high probability. Constellations are formed only from candidate facial features that lie inside the appropriate locations, and the ranking of constellation is based on a probability density function that a constellation corresponds to a face versus the probability it was generated by the non-face mechanism. In their experiments, this system is able to achieve a correct localization rate of 86% for cluttered images.

Template matching methods

In this category, several standard patterns of a face are stored to describe the face as a whole or the facial feature separately. The correlations between an input image and the stored pattern are computed for detection. These methods have been used for both face localization and detection. The following subsection summarizes an excellent face detection technique based on deformable template matching, where the template of faces is deformable according to some defined rules and constraints.

Adaptive appearance model

In the traditional deformable template matching techniques, the deformation constraints are determined based on user-defined rules such as first- or second-order derivative properties. These constraints are seeking for the smooth nature or some prior knowledge, while not all the patterns we are interested in have these properties. Furthermore, the traditional techniques are mainly used for shape or boundary matching, not for texture matching.

V. COMPARISON AND CONCLUSION

In this section, we'll give summaries on face detection and face recognition techniques during the past twenty year as well as popular face data set for experiments and their characteristics.

Method	Category	Characteristics
Hierarchical knowledge-based	Knowledge-based	Coarse-to-fine procedure
Horizontal / vertical projection	Knowledge-based	
Face Detection Using Color Information	Feature-based	Combining skin-color detection, face shape verification, and facial feature configuration for detection
Face detection based on random labelled graph matching graph matching [11]	Feature-based	Combining simple features with statistical learning and estimation
Active appearance model	Template matching	Learning facial shape and appearance variation by data
Example-based learning	Appearance-based	Learning the face and non-face distribution by mixture of Gaussian
Haar features with Ad boost	Appearance-based	Ad boost for speed-up
Generative models	Part-based	Unsupervised extracting important facial features, and learning the relation among parts and discrimination
Component-based with SVM	Part-based	Learning global and local SVM for detection

Table 2: The summary of face detection techniques

Method	Category	Characteristics
PCA	Holistic-based	PCA for learning Eigen faces, unsupervised
LDA	Holistic-based	LDA for learning fisher faces, supervised
2D-PCA	Holistic-based	2D-PCA for better statistical properties
ICA	Holistic-based	ICA for catch facial independent components, two architectures are proposed
Laplacian faces	Holistic-based	Nonlinear dimension reduction for finding bases, LPP

Evolutionary pursuit	Holistic-based	Using the genetic algorithm for finding the best projection bases based on generalization error
Kernel PCA And Kernel LDA	Holistic-based	Mapping the image into higher-dimensional space by the kernel function, and exploit the PCA and LDA bases there
Sparse representation	Holistic-based	Using L1 minimization and over-complete dictionary for finding sparse representation
Gabor and dynamic link architecture	Feature-based	Gabor features extracted at facial feature locations, while performing one-by-one matching
Gabor and elastic bunch graph matching	Feature-based	Gabor features extracted at facial feature locations, and obtaining the robust representation by the FBG matching.
LBP	Feature-based	Local binary patterns are introduced
LTP	Feature-based	Binary into ternary
AAM	Template matching	AAM parameters for classification learning
Component-based	Part-based	Comparing global and component
SIFT	Part-based	Using SIFT feature with spatial constraints to

Table 3: The summary of face recognition techniques

Name	RGB/gray	Image size	# people	Pictures/person	Conditions	Available
AR Face Database*	RGB	576x768	126	26	i, e, o, t	Yes
Richard's MIT	RGB	480x640	154	6	p, o	Yes
CVL	RGB	640x480	114	7	p, e	Yes
The Yale Face Database	Gray	640x480	10	576	p, i	Yes
The Yale Face Database*	Gray	320x243	15	11	i, e	Yes
PIE*	RGB	640x486	68	~608	p ,i, e	Yes
The UMIST Face	Gray	220x220	20	19-36	p	Yes
Olivetti Att-ORL*	Gray	92x112	40	10		Yes
JAFFE	Gray	256x256	10	7	e	Yes
The Human Scan	Gray	384x286	23	~66		Yes
XM2VTSDB	RGB	576x720	295		p	With pay
FERET*	RGB/gray	256x384	30000		p, i, e,	Yes

Table 4: The summary of popular databases used for detection and recognition tasks

The (*) points out most used databases. Image variations are indicated by (i) illumination, (p) pose, (e) expression, (o) occlusion, (i/o) indoor/outdoor conditions and (t) time delay.