**FACE RECOGNITION:**

* ***Face recognition is a method of identifying or verifying the identity of an individual using their face.***
* Face recognition systems can be used to identify people in photos, video, or in real-time.
* But face recognition data can be prone to error, which can implicate people for crimes they haven’t committed.
* Facial recognition software is particularly bad at recognizing African Americans and other ethnic minorities, women, and young people, often misidentifying or failing to identify them, disparately impacting certain groups.
* Additionally, face recognition has been used to target people [engaging in protected speech](http://www.baltimoresun.com/news/maryland/crime/bs-md-geofeedia-update-20161011-story.html).
* In the near future, face recognition technology will likely become more ubiquitous.
* **Face recognition systems use computer algorithms to pick out specific, distinctive details about a person’s face.**
* These details, such as distance between the eyes or shape of the chin, are then converted into a mathematical representation and compared to data on other faces collected in a face recognition database.
* T**he data about a particular face is often called a face template and is distinct from a photograph** because it’s designed to only include certain details that can be used to distinguish one face from another.
* **Some face recognition systems, instead of positively identifying an unknown person, are designed to calculate a probability match score between the unknown person and specific face templates stored in the database**. These systems will offer up several potential matches, ranked in order of likelihood of correct identification, instead of just returning a single result.
* **Face recognition systems vary in their ability to identify people under challenging conditions** such as poor lighting, low quality image resolution, and suboptimal angle of view (such as in a photograph taken from above looking down on an unknown person).
* When it comes to errors, there are two key concepts to understand:

**A “false negative” is when the face recognition system fails to match a person’s face to an image** that is, in fact, contained in a database. In other words, the system will erroneously return zero results in response to a query.

**A “false positive” is when the face recognition system does match a person’s face to an image in a database**, but that match is actually incorrect. This is when a police officer submits an image of “Joe,” but the system erroneously tells the officer that the photo is of “Jack.”

When researching a face recognition system, it is important to look closely at the “false positive” rate and the “false negative” rate, since there is almost always a trade-off.

***For example, if you are using face recognition to unlock your phone, it is better if the system fails to identify you a few times (false negative) than it is for the system to misidentify other people as you and lets those people unlock your phone (false positive). If the result of a misidentification is that an innocent person goes to jail (like a misidentification in a mugshot database), then the system should be designed to have as few false positives as possible.***

**How facial recognition works**

Facial recognition is the process of identifying or verifying the identity of a person using their face. It captures, analyzes, and compares patterns based on the person's facial details.

1. The **face detection process** is an essential step in detecting and locating human faces in images and videos.
2. The **face capture** process transforms analog information (a face) into a set of digital information (data or vectors) based on the person's facial features.
3. The **face match** process verifies if two faces belong to the same person.

* The process of facial recognition starts with the human face and identifying its necessary facial features and patterns.
* A human face comprises a very basic set of features, such as eyes, nose, and mouth.
* Facial recognition technology learns what a face is and how it looks.
* This is done by using deep neural network & machine learning algorithms on a set of images with human faces looking at different angles or positions.
* The process starts with detecting the human eyes, one of the most accessible features to detect, and then proceeds to detect eyebrows, nose, mouth, etc.
* Calculating the width of the nose, the distance between the eyes, and the shape & size of the mouth, the model created tries to find insights from the facial region.
* Multiple algorithm training can be performed to improve the algorithm’s accuracy to detect the faces and their positions. Once the face is detected, the model is then trained further with the help of computer vision algorithms to detect the facial landmark features such as eyebrow corners, eyes gap, the tip of the nose, mouth corners, etc.
* Each feature is considered as a nodal point, and each face consists of around 80 nodal points. These landmark features are the key to distinguish each face present in the database.
* After the facial features are extracted, landmarks, face position, orientation & all key elements are fed into the model; the model generates a unique feature vector for each face in its numeric form.
* A unique code generated identifies the person among all the others in the dataset. The generated feature vector is then used to search and match from the entire dataset or database of faces present during the face detection process

### **Why face recognition, then?**

* Facial biometrics continues to be the preferred biometric benchmark.
* That's because it's easy to deploy and implement. There is no physical interaction with the end-user.
* Moreover, face detection and face match processes for verification/identification are speedy.

***FACE RECOGNITION TECHNIQUES:***

There are different methods for face recognition, which are as follows-

**Geometric Based / Template Based:-**

* Face recognition algorithms classified as geometry based or template based algorithms.
* The template-based methods can be constructed using statistical tools like SVM [Support Vector Machines], PCA [Principal Component Analysis], LDA [Linear Discriminant Analysis], Kernel methods or Trace Transforms.
* The geometric feature based methods analyse local facial features and their geometric relationship. It is also known as a feature-based method.

# **Piecemeal / Wholistic:-**

* The relation between the elements or the connection of a function with the whole face not undergone into the amount, many researchers followed this approach, trying to deduce the most relevant characteristics.
* Some methods attempted to use the eyes, a combination of features and so on.
* Some Hidden Markov Model methods also fall into this category, and feature processing is very famous in face recognition.

**Appearance-Based / Model-Based:-**

* The appearance-based method shows a face regarding several images.
* An image considered as a high dimensional vector.
* This technique is usually used to derive a feature space from the image division.
* The sample image compared to the training set.
* On the other hand, the model-based approach tries to model a face.
* The new sample implemented to the model and the parameters of the model used to recognise the image.
* The appearance-based method can classify as linear or nonlinear.
* For Example - PCA, LDA, IDA used in direct approach whereas Kernel PCA used in nonlinear approach.
* On the other hand, in the model-based method can be classified as 2D or 3D Ex- Elastic Bunch Graph Matching used.

# **Template / Statistical / Neural Networks Based:-**

## Template Matching:

* In template matching the patterns are represented by samples, models, pixels, textures, etc.
* The recognition function is usually a correlation or distance measure.

## Statistical Approach:

* In the Statistical approach, the patterns expressed as features.
* The recognition function in a discriminant function.
* Each image represented regarding d features.
* Therefore, the goal is to choose and apply the right statistical tool for extraction and analysis.
* There are many statistical tools, which used for face recognition.
* These analytical tools used in a two or more groups or classification methods.

These tools are as follows

## Principal Component Analysis

## Discrete Cosine Transform

## Linear Discriminant Analysis

## Locality Preserving Projections

## Gabor Wavelet

## Independent Component Analysis

## Kernel PCA

## Neural Networks:

* Neural Network has continued to use pattern recognition and classification. There are methods, which perform feature extraction using neural networks. There are many methods, which combined with tools like PCA or LCA and make a hybrid classifier for face recognition.
* These are like Feed Forward Neural Network with additional bias, Self-Organizing Maps with PCA, and Convolutional Neural Networks with multi-layer perception, etc.
* These can increase the efficiency of the models.

These could be further divided as:

## Neural Networks with Gabor Filters

## Neural Networks and Hidden Markov Models

## Fuzzy Neural Networks

***FACE DETECITION:***

* Face detection -- also called facial detection -- is an [artificial intelligence](https://searchenterpriseai.techtarget.com/definition/AI-Artificial-Intelligence) (AI) based computer technology used to find and identify human faces in digital images.
* Face detection technology can be applied to various fields -- including security, [biometrics](https://searchsecurity.techtarget.com/definition/biometrics), law enforcement, entertainment and personal safety -- to provide surveillance and tracking of people in real time.
* Face detection has progressed from rudimentary [computer vision](https://searchenterpriseai.techtarget.com/definition/machine-vision-computer-vision) techniques to advances in machine learning ([ML](https://searchenterpriseai.techtarget.com/definition/machine-learning-ML)) to increasingly sophisticated artificial neural networks ([ANN](https://searchenterpriseai.techtarget.com/definition/neural-network)) and related technologies; the result has been continuous performance improvements.
* It now plays an important role as the first step in many key applications -- including face tracking, face analysis and [facial recognition](https://searchenterpriseai.techtarget.com/definition/facial-recognition). Face detection has a significant effect on how sequential operations will perform in the application.
* In face analysis, face detection helps identify which parts of an image or video should be focused on to determine age, gender and emotions using facial expressions.
* In a facial recognition system -- which maps an individual's facial features mathematically and stores the data as a faceprint -- face detection data is required for the [algorithms](https://whatis.techtarget.com/definition/algorithm) that discern which parts of an image or video are needed to generate a faceprint.
* Once identified, the new faceprint can be compared with stored faceprints to determine if there is a match.

### ***How face detection works***

* Face detection applications use algorithms and ML to find human faces within larger images, which often incorporate other non-face objects such as landscapes, buildings and other human body parts like feet or hands.
* Face detection algorithms typically start by searching for human eyes -- one of the easiest features to detect. The algorithm might then attempt to detect eyebrows, the mouth, nose, nostrils and the iris.
* Once the algorithm concludes that it has found a facial region, it applies additional tests to confirm that it has, in fact, detected a face.
* To help ensure accuracy, the algorithms need to be trained on large [data sets](https://whatis.techtarget.com/definition/data-set) incorporating hundreds of thousands of positive and negative images.
* The training improves the algorithms' ability to determine whether there are faces in an image and where they are.

***METHODS USED IN FACED DETECTION:***

The methods used in face detection can be knowledge-based, feature-based, template matching or appearance-based. Each has advantages and disadvantages:

* **Knowledge-based, or rule-based methods**, describe a face based on rules. The challenge of this approach is the difficulty of coming up with well-defined rules.
* **Feature invariant methods** -- which use features such as a person's eyes or nose to detect a face -- can be negatively affected by noise and light.
* **Template-matching methods** are based on comparing images with standard face patterns or features that have been stored previously and correlating the two to detect a face. Unfortunately these methods do not address variations in pose, scale and shape.
* **Appearance-based methods** employ statistical analysis and machine learning to find the relevant characteristics of face images. This method, also used in feature extraction for face recognition, is divided into sub-methods.

***TECHNIQUES USED WHILE PERFORMING FACE DETECTION***

Some of the more specific techniques used in face detection include:

* Removing the background. For example, if an image has a plain, mono-color background or a pre-defined, static background, then removing the background can help reveal the face boundaries.
* In color images, sometimes skin color can be used to find faces; however, this may not work with all complexions.
* Using motion to find faces is another option. In real-time video, a face is almost always moving, so users of this method must calculate the moving area. One drawback of this method is the risk of confusion with other objects moving in the background.
* A combination of the strategies listed above can provide a comprehensive face detection method.
* Detecting faces in pictures can be complicated due to the variability of factors such as pose, expression, position and orientation, skin color and pixel values, the presence of glasses or facial hair, and differences in camera gain, lighting conditions and image resolution.
* Recent years have brought advances in face detection using [deep learning](https://searchenterpriseai.techtarget.com/definition/deep-learning-deep-neural-network), which presents the advantage of significantly outperforming traditional computer vision methods.
* To help eliminate the drawbacks and improve face detection, other algorithms -- such as region-based convolutional neural network (R-CNN) and Single Shot Detector (SSD) -- have been developed to help improve processes.
* A [convolutional neural network](https://searchenterpriseai.techtarget.com/definition/convolutional-neural-network) (CNN) is a type of artificial neural network used in [image recognition](https://searchenterpriseai.techtarget.com/definition/image-recognition)and processing that is specifically designed to process pixel data. An R-CNN generates region proposals on a CNN framework to localize and classify objects in images.

**While region proposal network-based approaches such as R-CNN need two shots -- one for generating region proposals and one for detecting the object of each proposal -- SSD only requires one shot to detect multiple objects within the image. Therefore, SSD is significantly faster than R-CNN.**

### ***Advantages of face detection***

As a key element in facial imaging applications, such as facial recognition and face analysis, face detection creates various advantages for users, including:

* **Improved security**. Face detection improves surveillance efforts and helps track down criminals and terrorists. Personal security is also enhanced since there is nothing for hackers to steal or change, such as passwords.
* **Easy to integrate**. Face detection and facial recognition technology is easy to integrate, and most solutions are compatible with the majority of security software.
* **Automated identification**. In the past, identification was manually performed by a person; this was inefficient and frequently inaccurate. Face detection allows the identification process to be automated, thus saving time and increasing accuracy.

### ***Disadvantages of face detection***

While face detection provides several large benefits to users, it also holds various disadvantages, including:

* **Massive data storage burden**. The ML technology used in face detection requires powerful [data storage](https://searchstorage.techtarget.com/definition/storage) that may not be available to all users.
* **Detection is vulnerable**. While face detection provides more accurate results than manual identification processes, it can also be more easily thrown off by changes in appearance or camera angles.
* A **potential breach of privacy**. Face detection's ability to help the government track down criminals creates huge benefits; however, the same surveillance can allow the government to observe private citizens. Strict regulations must be set to ensure the technology is used fairly and in [compliance](https://searchdatamanagement.techtarget.com/definition/compliance) with human privacy rights.

### ***Face detection vs. face recognition***

Although the terms face detection and face recognition are often used together, facial recognition is only one application for face detection -- albeit one of the most significant ones. Facial recognition is used for unlocking phones and mobile apps as well as for Biometric verification. The banking, retail and transportation-security industries employ facial recognition to reduce crime and prevent violence.

In short, the term face recognition extends beyond detecting the presence of a human face to determine whose face it is. The process uses a computer application that captures a digital image of an individual's face -- sometimes taken from a video frame -- and compares it to images in a database of stored records.

***DEEP FACE :***

* Deepface is a lightweight [face recognition](https://sefiks.com/2018/08/06/deep-face-recognition-with-keras/) and facial attribute analysis ([age](https://sefiks.com/2019/02/13/apparent-age-and-gender-prediction-in-keras/), [gender](https://sefiks.com/2019/02/13/apparent-age-and-gender-prediction-in-keras/), [emotion](https://sefiks.com/2018/01/01/facial-expression-recognition-with-keras/) and [race](https://sefiks.com/2019/11/11/race-and-ethnicity-prediction-in-keras/)) framework for python.
* It is a hybrid face recognition framework wrapping **state-of-the-art** models: [VGG-Face](https://sefiks.com/2018/08/06/deep-face-recognition-with-keras/), [Google FaceNet](https://sefiks.com/2018/09/03/face-recognition-with-facenet-in-keras/), [OpenFace](https://sefiks.com/2019/07/21/face-recognition-with-openface-in-keras/), [Facebook DeepFace](https://sefiks.com/2020/02/17/face-recognition-with-facebook-deepface-in-keras/), [DeepID](https://sefiks.com/2020/06/16/face-recognition-with-deepid-in-keras/), [ArcFace](https://sefiks.com/2020/12/14/deep-face-recognition-with-arcface-in-keras-and-python/) and [Dlib](https://sefiks.com/2020/07/11/face-recognition-with-dlib-in-python/).
* Those models already reached and passed the human level accuracy.

**DeepFace is a**[**deep learning**](https://en.wikipedia.org/wiki/Deep_learning)[**facial recognition system**](https://en.wikipedia.org/wiki/Facial_recognition_system)**created by a research group at**[**Facebook**](https://en.wikipedia.org/wiki/Facebook)**. It identifies human faces in digital images. The program employs a nine-layer**[**neural network**](https://en.wikipedia.org/wiki/Neural_network)**with over 120 million connection weights and was**[**trained**](https://en.wikipedia.org/wiki/Machine_learning)**on four million images uploaded by Facebook users.**[**[1]**](https://en.wikipedia.org/wiki/DeepFace#cite_note-TechnologyReview2014-1)[**[2]**](https://en.wikipedia.org/wiki/DeepFace#cite_note-CBS2014-2)**The Facebook Research team has stated that the DeepFace method reaches an accuracy of 97.35% ± 0.25% on Labeled Faces in the Wild (LFW) data set where human beings have 97.53%.**[**[3]**](https://en.wikipedia.org/wiki/DeepFace#cite_note-3)**This means that DeepFace is sometimes more successful than the human beings**.

***OpenCV vs OpenFace:***

**OpenCV:** *Open Source Computer Vision Library*. OpenCV was designed for computational efficiency and with a strong focus on real-time applications. Written in optimized C/C++, the library can take advantage of multi-core processing. Enabled with OpenCL, it can take advantage of the hardware acceleration of the underlying heterogeneous compute platform.

**OpenFace:** *Free and open source face recognition with deep neural networks*. OpenFace is a Python and Torch implementation of face recognition with deep neural networks and is based on the CVPR 2015 paper FaceNet: A Unified Embedding for Face Recognition and Clustering by Florian Schroff, Dmitry Kalenichenko, and James Philbin at Google.

OpenCV belongs to **"Image Processing and Management"** category of the tech stack, while OpenFace can be primarily classified under **"Facial Recognition"**.

Some of the features offered by OpenCV are:

* C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS and Android
* More than 47 thousand people of user community and estimated number of downloads exceeding 7 million
* Usage ranges from interactive art, to mines inspection, stitching maps on the web or through advanced robotics

On the other hand, OpenFace provides the following key features:

* Detect faces with pre-trained models
* Transform faces for the neural network
* Use deep neural networks to reprsent or embed the face on a hypersphere

**Alternatives to OpenCV and OpenFace:**

**TensorFlow**

TensorFlow is an open source software library for numerical computation using data flow graphs. Nodes in the graph represent mathematical operations, while the graph edges represent the multidimensional data arrays (tensors) communicated between them. The flexible architecture allows you to deploy computation to one or more CPUs or GPUs in a desktop, server, or mobile device with a single API.

**CImg**

It mainly consists in a (big) single header file CImg.h providing a set of C++ classes and functions that can be used in your own sources, to load/save, manage/process and display generic images.

**OpenGL**

It is a cross-language, cross-platform application programming interface for rendering 2D and 3D vector graphics. The API is typically used to interact with a graphics processing unit, to achieve hardware-accelerated rendering.

**PyTorch**

PyTorch is not a Python binding into a monolothic C++ framework. It is built to be deeply integrated into Python. You can use it naturally like you would use numpy / scipy / scikit-learn etc.

**OpenCL**

It is the open, royalty-free standard for cross-platform, parallel programming of diverse processors found in personal computers, servers, mobile devices and embedded platforms. It greatly improves the speed and responsiveness of a wide spectrum of applications in numerous market categories including gaming and entertainment titles, scientific and medical software, professional creative tools, vision processing, and neural network training and inferencing.

***In terms of speed, HoG seems to be the fastest algorithm, followed by Haar Cascade classifier and CNNs. However, CNNs in Dlib tend to be the most accurate algorithm. HoG perform pretty well but have some issues identifying small faces. HaarCascade Classifiers perform around as good as HoG overall.***