FingerTec® FACE RECOGNITION TECHNOLOGY WHITE PAPER

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SCOPE

FingerTec® face recognition technology is a biometrics technique based on real-time capturing of three-dimensional (3D) images of a subject's face for extra accuracy and security as authentication method.

FingerTec® face recognition technology is the foundation for all face recognition solutions from FingerTec® and it operates seamlessly with various third-party security applications, smart cards readers and biometrics devices in the market. This paper describes the principles and advantages of FingerTec®'s face recognition technology.

INTRODUCTION

Face recognition has become one of the most important biometrics authentication technologies in the past few years. Two main reasons for extensive attention on face recognition technology are: 1) Aptness in various applications including in content-based video processing system, law enforcement system and in security systems. A strong need for a robust automatic system is obvious due the widespread use of photo-ID for personal identification and security 2) although there are reliable methods of biometrics identifications existed such as fingerprint scans and iris scans, face recognition is proven effective for its user-friendliness. The system does not require its users to do anything; it is contactless. On top, as one of the core components, the maturity of the digital camera technology with competitive price, is also a contributing factor to the strong emergence of face recognition technology.

Three-dimensional face recognition is a relatively recent trend that in some sense breaks the long-term tradition of mimicking the human visual recognition system, like the 2D methods attempt to do. As evaluations such as the Face Recognition Vendor Test (FRVT) demonstrate in an unarguable manner that current state of the art in 2D face recognition is insufficient for high-demanding biometric applications (Phillips et al., 2003), trying to use 3D information has become an emerging research direction in hope to make face recognition more accurate and robust.

This article discusses two main algorithm families commonly used to recognize faces: two-dimensional based and three-dimensional based recognition. Both of these two algorithms recognize faces images in different ways; two-dimensional algorithm is based on information theory concepts, seeks a computational model that best describes a face by extracting the most relevant information contained in that face while three-dimensional facial geometry represents the internal anatomical structure of the face rather than its external appearance influenced by environmental factors. As will be shown in this article, both algorithms have advantages and disadvantages. FingerTec® continuing research and development efforts have led to a more accurate and robust technology known as the FingerTec® Face Recognition Solution.

Over the past decades, FingerTec® had placed concentration on development of face recognition methods within the framework of biometrics security systems and now is ready to apply the technology to other markets. FingerTec® face recognition technology can be implemented as a functionally independent application, or seamlessly integrated into new or existing biometrics security solutions by system integrators and solution providers.

FingerTec® face recognition technology utilizes the 3D face recognition algorithm that provides high speed and high accuracy for facial detection and facial features extraction. The three-dimensional representations of the head are then rotated in both the left-to-right and up-and-down directions. Further processing applies differing illumination across the face, which greatly enhanced the chances of a query "faceprint" for matching against its true mate from the database. To reduce the impact of adverse local changes (e.g., varying facial expression caused by smiling and blinking eyes, and intentional changes caused by the wearing of caps, hats and glasses), FingerTec® face recognition technology also reduces the impact of adverse local changes (e.g., varying facial expression caused by smiling and blinking eyes, and intentional changes caused by wearing of caps, hats and glasses) during the matching process.

Two Dimensional Face Recognition - PCA

We use Principal Component Analysis (PCA) to discuss the concept of two dimensional face recognition technology. Principal component analysis (PCA) is one of the widely used 2D face recognition algorithms. It is based on information theory concepts, seeks a computational model that best describes a face by extracting the most relevant information contained in that face. The Eigenfaces approach is a PCA method, in which a small set of characteristic pictures are used to describe the variation between face images. The goal is to find the eigenvectors (eigenfaces) of the covariance matrix of the distribution, spanned by training a set of face images. Later, every face image is represented by a linear combination of these eigenvectors. Recognition is performed by projecting a new image onto the subspace spanned by the eigenfaces and then classifying the face by comparing its position in the face space with the positions of known individuals.

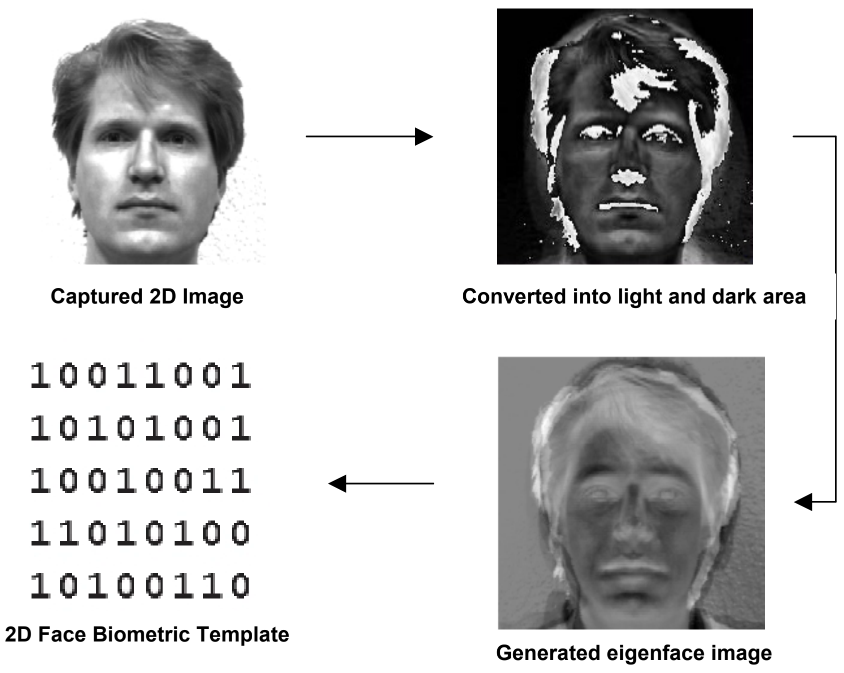


Figure 1: 2D Face Recognition Process

Pros:

- Fast, needs lesser amount of memory for identification.
- Image template size small.

Cons:

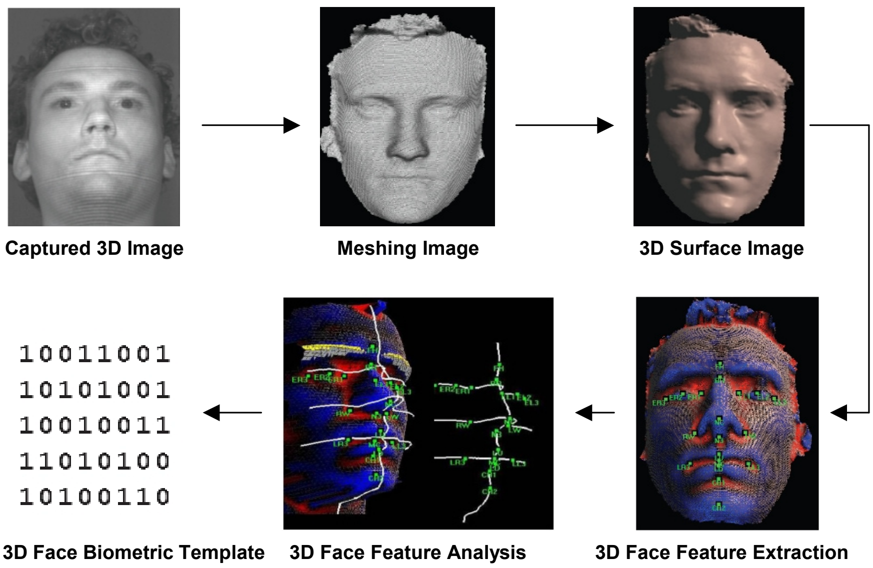
- 2D face recognition algorithm is sensitive to lighting, head orientations, facial expressions and makeup.
- 2D images contain limited information.

The PCA-eigenfaces system capture the image and change it to light and dark areas. Both the initial facial image and facial image in question are also captures in a two-dimensional form. Then, the two images are compared according to the points of the two eigenface image. It picks out certain features and calculates the distances between them. The points are the facial features such as eyes, nose, mouth, bone curves, and other distinct features. The eigenface algorithm firstly forms overall average image. This is the image just adding all images and dividing by number of images in training set. And the eigenvectors of covariance matrix that is formed by combining all deviations of training set's images from average iamge is formed in order to applu eigenfaces algorithm. After finding overall average image, the order is to find eigenvectors of the covariance matrix. Visualization of eigenvectors is carried out simply applying a quantization that is if the found eigenvectors have components that are greater than 255 and smaller than 0 round them to 255, and 0 respectively.

Three Dimensional Face Recognition

Three-dimensional face recognition (3D face recognition) is a modality of facial recognition methods in which the three-dimensional geometry of the human face is used. 3D face recognition has the potential to achieve better accuracy than its 2D counterpart by measuring geometry of rigid features on the face. This avoids such pitfalls of 2D face recognition algorithms as change in lighting, different facial expressions, make-up and head orientation. Another approach is to use the 3D model to improve accuracy of traditional image based recognition by transforming the head into a known view. Additionally, most range scanners acquire both a 3D mesh and the corresponding texture. This allows combining the output of pure 3D matchers with the more traditional 2D face recognition algorithms, thus yielding better performance (as shown in FRVT 2006). The main technological limitation of 3D face recognition methods is the acquisition of 3D images, which usually requires a range camera. This is also a reason why 3D face recognition methods have emerged significantly later (in the late 1980s) than 2D methods. Recently commercial solutions have implemented depth perception by projecting a grid onto the face and integrating video capture of it into a high resolution 3D model. This allows for good recognition accuracy with low cost off-the-shelf components.

Figure 2: 3D Face Recognition Process



Pros:

- 3D Representation of face is less susceptible to isometric deformations (expression changes).
- 3D approach overcomes problem of large facial orientation changes.
- 3D model retains all the information about the facial features, a more accurate representation of the facial features leads to potentially higer discriminating power.
- Robustness to lighting and angles up to 45º.

Cons:

- Less nimble at processing large crowds templates.
- Computational cost of processin 3D data is higer than for 2D data.

3D Face recognition system consists of four modules: Device Module, Data Processing Module, Feature Extraction Module and Matching Engine Module. The Device Module acquires initial 3D facial data by a 3D surface scanner VGA camera and transfers it to the processor. After receiving raw data (the distorted pattern on the target object), the Data Processing Module performs image filtering (noise reduction) and then instantly reconstructs the 3D surface, smoothing and Interpolating data to avoid holes and optimize the mesh. The Feature Extraction Module receives the optimized 3D surface for further feature vector (biometric template) extraction. During biometric template extraction, a proprietary two-stage algorithm is used. At the first stage, the surface "semantic analysis" is performed, resulting in the location of key crania-facial landmarks (points) on the facial surface and the fitting of the surface to a generic topological map of the face. At the second stage, when the location of specific surface patches (eye-sockets, super ciliary's arches, forehead zone, nasolabial zone, chin zone, etc.) is known, information about local surface curvature characteristics is extracted. This local curvature information is used further to build a single geometric descriptor and packs this data into a biometric template. The output of the module is a biometric template uniquely characterizing the person, which is used in the next matching stage. The Matching Engine working in identification mode compares the extracted biometric template with all of the stored templates in the database and produces a similarity score for each of the stored templates. The template with the best similarity score is the top match.

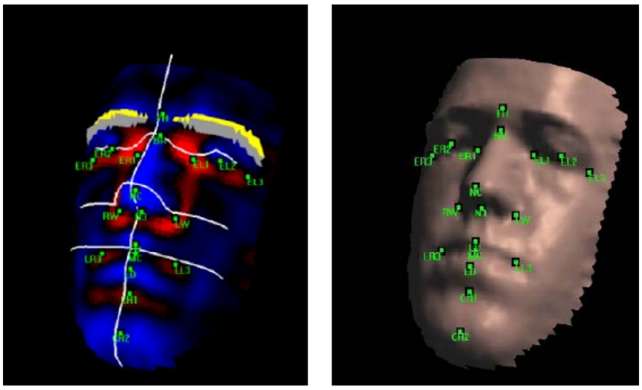
2D vs 3D Face Recognition

	Two Dimention **2D**	Three Dimention **3D**
Definition	The eigenvectors of the two-dimensional vector space of possible faces of human beings.	A class of methods that work on a 3D dataset, representing both face and head shape as range data or polygonal meshes.
How it works	An initial set of 2D face images were acquired. The Eigenfaces were calculated from the training set. Only M Eigenfaces correspon-ding to the M largest eigenvalues were retained. These Eigenfaces spanned the face space which constituted of the training set. The M Eigenface-weights were calculated for each training image by projecting the image onto face space spanned by the Eigenfaces. Each face image then will be represented by M weights- an extremely compact representation.	The Device Module acquires initial 3D facial data and transfers it to the processor. The Data Processing Module reconstructs the 3D surface for further recognition. The Feature Extraction Module builds the feature vector (biometric template), based on the 3D surface reconstructed for further use in the matching process. The Matching Engine Module provides a comparison of acquired and previously enrolled biometric templates.
Template size	Small template size (800 bytes to 2 kilobytes).	Compact biometric template extracted (2-4 kilobytes).
Template Descipt0n	Face features locations, texture or combination. NOT a real measument	Description of face shape in 3D face geometry, full features description. Gound-based measurement (sub-milimetre)
Liveness Testing	May be spoofed by photo or video	NOT to be spoofed by video or photo
FAR	0.001 (FRVT2006 result)	0.001 (FRVT2006 result)
FRR	0.010-0.017 (FRVT2006 result)	0.005-0.015(FRVT2006 result)
Accuracy	Medium, fully depending to image resolution.	High, not so depending to image resolution.
Sensitivity	Sensitive to lighting, pose, makeup or expressions.	Insensitive to lighting, make up and pose up to 45º. Sensitive to expressions.
Standard	ANSI INCITS 385-2004 ISO –19794-5 FDIS	ANSI INCITS 385-2004 ISO/IEC JTC1 SC37 WG3
Leading Vendors	Neven-Vision, Sagem	Identix®, FingerTec®

FingerTec® Face Recognition Algorithm

FingerTec® face recognition algorithm takes advantage of the 3D face recognition that is invariance to lighting and accurate to angles up to 45 degree; offering robust and precise identification in real life environments.

Benefits of FingerTec® Face Recognition Algorithm:



3D Face Geometry Features

1. FingerTec® face recognition algorithm is able to process a maximum of 2000 faces for 1 to N identification without requiring any pre-entered PIN or name, within 5 seconds (based on CPU Pentium 4 2.4GHz).
2. FingerTec® face recognition algorithm current 3D approach provides a measure for automatic and robust estimation of input stream quality. This measure is computationally efficient and allows for estimation of the quality of input surface and attribution of it to one of tow classes: face or not a face. This means that not only enrollment can be automatically controlled but also all subsequent face acquisitions.
3. FingerTec® face recognition algorithm is more robust to different view angles between the enrollment and captured shots, with robust recognition up to 45°. Therefore, FingerTec® approach has the potential to work with higher accuracy in real work environments.
4. FingerTec® face recognition's technique uses direct geometric measurements available from 3D images (range images), providing sub-millimeter geometric information. This 3D geometry is invariant to ambient light conditions and may even be used in the darkness. So it's robust to lighting condition.
5. The FingerTec® face recognition products cannot be spoofed by video or photograph images. In addition, it is extremely difficult to fool the system with 3D dummy or mask, as a precise stereo-lithographic model is required with the same sub-millimeter geometric measurements. In addition, the light pattern in the near infrared range is reflected and diffracted in a specific manner against human skin.
6. FingerTec® 3D biometrics template is optimized according to the some given criteria, the 3D polygonal mesh is built from the cloud of the 3D points and the size is less than 5 kilobytes which reduced the storage requirements and enhanced the processing time.
7. FingerTec® face recognition able to process 10-12 full capturing-matching cycles per second for extremely low False Rejection Rates (FRR) and False Acceptance Rate (FAR) which is the leader in the processing and accuracy.

Algorithm Performance

FingerTec has gone through many tests based on different image capturing resolution, lighting environment, poses angles where 100000 faces images are obtained to test the performance of the FingerTec® face recognition algorithm in the past 2 years. The summary of the results is as below:

3D Face Enrollment Results:
- 98.9% automatic enrollment
- 1.1% required manual support
- 0% failure to enroll
- average 5-10 seconds enrollment time

3D Face Verification Results:
- False Accept Rate (FAR) <= 0.01%
- False Reject Rate (FRR) <= 0.1%
- Matching speed = 60000 faces / second

3D face recognition research has been very active and has made tremendous progress over the past few years. 3D face recognition systems have a lot of immediate applications as long as the environment can be controlled appropriately. An important lesson that we can draw from the history of face recognition is as follows: for very complex perception tasks, such as face recognition, it is not the most productive way to develop a system according to manually developed content level rules, rules that are directly related to the object to be perceived. For 3D face recognition, such rules include what facial features should be used, how face images may change if the lighting is changed, what facial changes one may see when one smiles, which part of the face is more invariant, etc. A general learning scheme, one that does not depend on the objects to be perceived can turn out to be very effective because it can adapt well to the objects without being impaired by the content-level rules.

Although the current 3D face recognition systems have achieved very good results for faces that are taken in a controlled environment, they perform poorly in less uncontrolled situations. Humans know how to take environmental context into account but our existing systems do not. A fundamental methodology revolution is necessary for a breakthrough advance from the current state of the art. It becomes increasingly evident that breakthrough solutions to tough computer vision problems can probably be found by looking beyond the visual modality. Therefore, 3D face recognition is still a challenging but very promising research area. FingerTec® will continuously run field test of the complete system to get statistics for continued improvement of the 3D face recognition performance.

