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A Survey on Newer Prospective Biometric Authentication Modalities

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Abstract. Biometric authentication technologies, such as fingerprint, face, iris, and vein, have been widespread in many applications from individual portable devices to national ID management systems. Furthermore, relatively newer biometric authentication modalities including eye movement, lip-motion, etc., have been also researched and developed in order to improve an authentication accuracy and an usability of a biometric authentication system. In addition, some these kind of modalities are effective as a liveness detection technique, which can not only improve authentication accuracy in traditional biometric authentication systems, but also decrease risks regarding anti-spoofing attacks. In this paper, we introduce some relatively newer prospective biometric authentication modalities related to face, hand, and some traits.

1. Introduction

Biometric authentication technologies have been widespread in many applications from individual portable devices to some national ID management systems, such as Aadhaar in India, and US-Visit in United States. As biometric authentication modalities, especially, fingerprint, face, iris, and vein authentication are commonly used in those systems, since the recognition technologies have already been enough feasible and practical for actual various business markets. Additionally, voice, gait, and signature are also well-known biometric modalities as a behavioral trait, which are utilized in some commercial systems.

Furthermore, relatively newer biometric authentication modalities have been also researched and developed in order to improve an authentication accuracy and an usability of a biometric authentication system. For example, some modalities have been researched for utilizing as a supplemental modality of traditional biometric authentication modality, such as eyebrow, eye movement, nose information, and so on. Additionally, in order to realize a continuous authentication system which can keep authenticating users during using the system, lip motion and cardiac information have been researched too. Biometric authentication technologies would be more utilized if relatively newer biometric authentication modalities become more practical.

In this paper, we introduce some relatively newer prospective biometric authentication modalities related to face, hand, and some traits in order to establish a foothold for realizing future biometric authentication systems . In section 2, some new features around a face are described, and features related to a hand/arm are introduced in section 3. In section 4, we introduce some techniques using cardiac information and stylometry as interesting biometric authentication modalities.

2. Facial Information

Face and iris verification technologies are often used for surveillance video systems, boarder controls, and access control managements of individual devices, such as mobile-phones, PCs, etc.. Recently, as actual face recognition systems become wide-spread, these technologies become more important, which is why it is important to evaluate various effects including not only illumination variations, various postures, and occlusion situations, but also effects of cosmetics[**13**], and transgender[**45**].

In this section, we introduce five prospective newer modalities are related to facial informations which allow us to realize more robust authentication systems for various posture, occlusion, etc..., such as *Eyebrow, Ear, Eye Movement, Nose, and Lip Motion.*

2.1. Eyebrow

In not only a face recognition system but also an iris recognition system, an image of an eyebrow can be captured simultaneously. Many eyebrow recognition techniques have been proposed in order to improve their authentication accuracy.

As a segmentation technique of eyebrow regions, Chen et al.[**10**] proposed the estimating and accurately extracting method using the snake algorithm to estimate a flexible 2D line which is moved around an image to minimize an energy function. Hollingsworth et al.[**27**] proposed a segmentation method based on active shape models (ASMs), which are statistical models of object shapes created by using training samples in Fig. 1. Wang et al.[**66**] proposed an eyebrow classification method using a contour shape of an eyebrow represented by cubic spline functions.

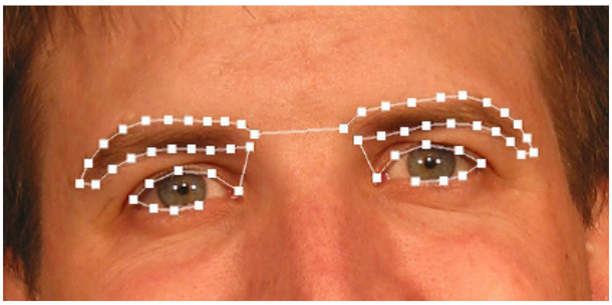

Figure 1. An example of segmented eyebrow regions based on ASMs[**27**]

Li et al.[**42**] conducted an experiment regarding HMM-based eyebrow recognition method, which HMM was trained by inputting an intensity sequence of an eyebrow image from left to right. Juefei-Xu et al.[**28**] evaluated some authentication performance, such as rank 1 rate, and ROC curves regarding features extracted from an eyebrow region. They used Local Binary Patterns (LBPs) as an eye brow feature, which is a descriptor of a patch image using local intensity differences.

Xiaojn et al.[**70**] discussed regarding eyebrow features based on sparsity preserving projections (SPP) which are compressive sensing methods, and they also introduced the combination of SPP and radon transform. In order to improve face recognition performance under non-ideal imaging conditions, such as motion blur, poor contrast, and various expressions, etc., Dong et al.[**14**] developed and evaluated three eyebrow recognition techniques based on Minimum Distance Classifier, Linear Discriminant Analysis Classifier, and Support Vector Machine Classifier.

2.2. Eye Movement

Eye movement has been researched in psychology and some medical fields for analyzing subjects' behavior and disease regarding their eyes. In the recent decade, eye movement information is used as one of biometric behavioral traits in order to use not only a supplemental feature, but also a continuous authentication method, and liveness detection for iris authentication techniques, and the first eye movement verification and identification competition was taken place in 2012[**30**].

In eye movement activities, there are two conditions, such as "Fixation" which is a condition an eye does not move, and "Saccade" which is a condition an eye moves quickly. Salvucci et al.[**58**] proposed some detection methods based on hiden markov model (HMM), velocity information, variation information of position, and etc.. Komogortsev et al.[**33**] discussed regarding not only fixation and saccade, but also a smooth pursuit which is a translation condition from saccade to fixation.

In terms of a feature extraction, Komogortsev et al.[**37**] proposed a mathematical model using an Oculomotor Plant Characteristics (OPC) which consists of nine scholar values, such as length tension represents an exterior muscle's length and strength , series elasticity represents a resistant of an eye muscle, etc. in Fig. 2. Holland et al.[**26**] proposed a statistical feature extraction method using twelve features, such as a horizontal average velocity during fixation and saccade, and evaluated some statistical tests for an authentication. According to the evaluation result, Kolmogorov-Smirnov test and Cramer-von Mises test are better than t-test for an authentication performance. Rigas et al.[**55**] proposed a graph-based matching in a velocity-acceleration space. Cuong et al.[**12**] proposed an authentication method using Mel-Frequency Cepstral Coefficients (MFCCs). Kinnunen et al.[**32**] mentioned a task-independent eye movement authentication technique which allows you to do an authentication without any specific instruction.

Furthermore, there are some combination methods using the above techniques, such as OPC+CEM[**35**], OPC+CEM+Iris[**36**]. Komogortsev et al.[**34**] discussed

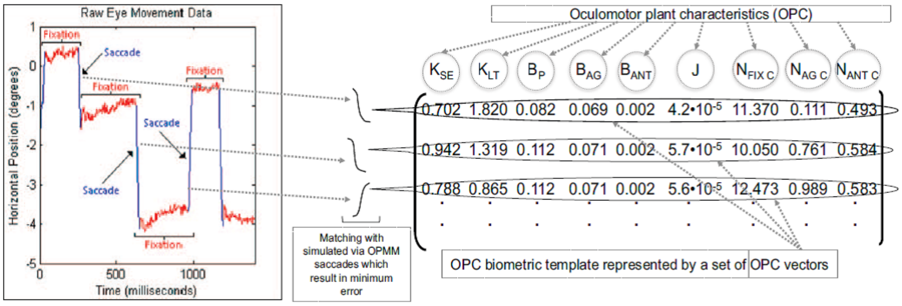

Figure 2. An example of eye movement features based on OPC[**37**]

regarding liveness detection using OPC features.

2.3. Ear

An ear shape recognition technologies have been researched in many forensics applications for about 100 years. Actually, a French criminologist conducted the first research in 1906, which was used only four different characteristics in order to distinguish between five-hundreds different ears[**54**]. As a ear information, Iannarelli's measurement is well known, which is based on twelve features(lengths) from the center to feature points of a ear in Fig. 3. A. Pfllug et al.[**54**] and Abaza et al.[**2**] summarized exhaustive research papers not only technical topics, such as detection/segmentation methods, feature extraction, and matching methods, but also many historical aspects.

In ear recognition techniques, template matching techniques, shape based techniques, Haar-based techniques, an ear contour extraction, and morphological operators are commonly used as a feature for an authentication. In terms of a matching method, intensity-based, force field, ear curves geometry, gabor filters, etc. have been researched.

Recently, research interests shift from basic authentication performance to some practical challenges, such as a partial occlusion[**5**], an expression change[**43**].

2.4. Nose

Generally speaking, in a frontal face, a nose shape is relatively robust for expression changes than other face parts, such as an eyebrow, an eye, and a mouse, which is why the nose recognition becomes important in face recognition techniques.

Chang et al.[**9**] discussed regarding nose region matching for 3D face recognition under varying facial expression. In the paper, the nose region is estimated using curvature information around the nose, which allows you to detect some feature regions, such as a nose peak region, PIT regions, and saddle regions. Then, a matching process is done based on an ICP algorithm. Moorhouse et al.[**51**] evaluated nose profile features as a biometric authentication modality, which is a

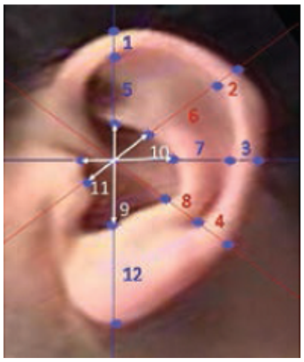

Figure 3. Iannarelli's measurement[2]

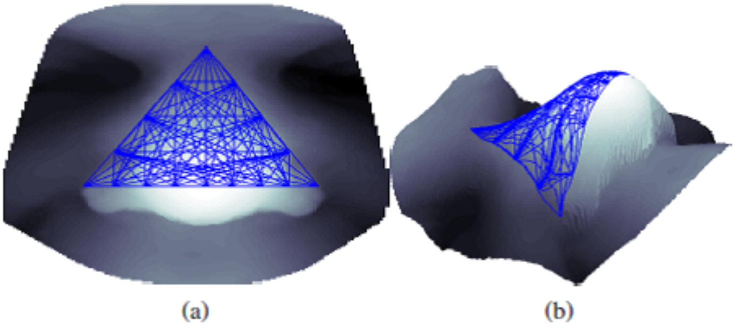

Figure 4. 3D nose representation by Faraj et al.[15]

line-based feature between a saddle to a nose tip.

Emambakhsh et al.[15] proposed a nasal curves matching algorithm for expression robust 3D nose recognition, which is based on length informations around nose feature points, and some general classifiers, such as Principal Component Analysis (PCA), Linear Descriminant Analysis (LDA), Support Vector Machine (SVM), and so on (see Fig. 4).

2.5. Lip Motion

Lip motion information is used as a supplemental modality to speech/voice authentication technologies, and used in an interactive person recognition system whose advantage is to be able to prevent impostor attacks with prerecorded speech data and video sequences, since the impostor cannot know what a subject have to say in advance.

Aravabhumi et al.[4] proposed a lip tracking method using a hue space information in order to mitigate illumination differences. Shipilova[62] proposed an

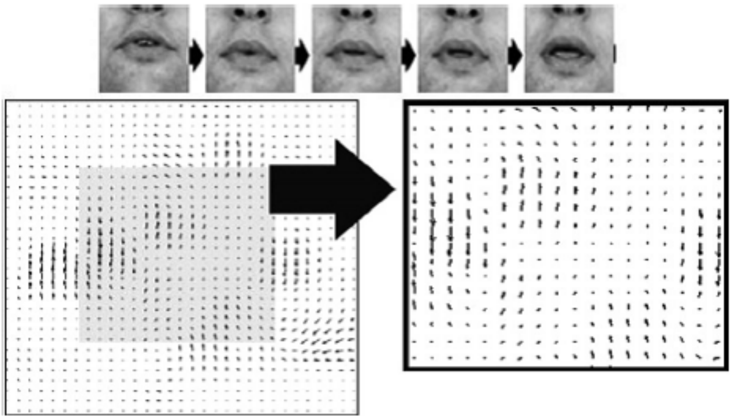

Figure 5. Lip motion feature based on optical flow[**18**]

authentication method using inner/external lip contours extracted by Active Shape Model (ASM), and an intensity information of the lip. Cetingul et al.[**8**] proposed an authentication method using not only lip intensity and geometry information, but also lip motion information which is Discrete Cosine Transform (DCT) informations around a mouse. Faraj et al.[**17**] proposed an authentication method with lip motion information using optical flow around a mouse, and a combination authentication method with a speech authentication technique[**18**] (see Fig. 5).

3. Hand / Wrist Information

Generally speaking, it is easier to input hand informations including finger informations and wrist informations than other body parts, because you can move their hand easily and the hand parts are not almost covered with clothes. In this section, we introduce finger knuckle print authentication, nail, touch-based or hand gestures as not only supplemental modalities but also the modalities improving usability of a traditional biometric authentication system.

3.1. Finger Knuckle Print

In some traditional biometric authentication systems, such as fingerprint, palmprint, Finger Knuckle Print(FKP) can be also captured simultaneously, which is why FKP is useful in order to improve their authentication performance without adding an extra device..

In the FKP *capture* stage, Finger Knuckle Sensor by Hong Kong Polytechnic University is often utilized[**1**], the sensor is specified to capture a FKP, and FKP is captured by bending the finger at the second joint. As for the other methods of capture, Cheng et al.[**11**] proposed a capturing system using a smart-phone camera

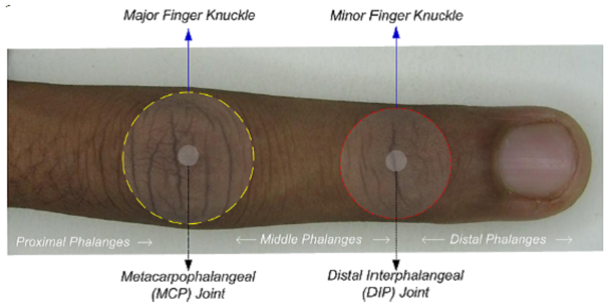

Figure 6. Finger knuckle prints at the first and the second joint[**38**]

while Aoyama et al.[**3**] proposed multi-finger knuckle authentication with a specific near infrared(NIR) camera for a door handle.

There are many methods to set the ROI of FKP area such as a method based on captured image character[**16**], extraction after converting HSV space[**41**], finger knuckle print detecting methods using the contour of a finger or hand[**38**], as well as adjusting ROI using the direction information to roughly estimate the finger knuckle region[**31**].

In terms of matching methods, the Gabor filter based methods[**60**], DAISY descriptor[**49**], Riesz transform[**71**], and combination of some features with using PCA or LDA have been proposed in [**39**][**61**][**60**].

In addition, there is some research being done not only on the finger knuckle modality, but also on combinations with other modalities such as Palm-print authentication[**47**] and fingerprint authentication[**48**]. Kumar et al.[**38**] proposed a method using both the first and second joint finger knuckle print (see Fig. 6).

3.2. Nail

There are some situations when dealing with non-critical scenarios and collaborative subjects, such as a key of a locker in a gym, a key which allows you to get into a hotel room. In these situations, some people will not be unwilling to provide a traditional biometric information such as fingerprint, iris information because it is generally impossible to change the information extracted from these modalities and they are concerning about a compromise risk of them. Barbosa et al.[**6**] discussed regarding a *transient* biometric information using a nail, which allows you to access to a protected area only in a certain period.

Garg et al.[**22**][**23**] proposed a nail plate biometric feature consists of Haar-wavelets. In this technique, a hand image is captured from the top-view by a camera, then three fingers' nails are extracted using finger-tip informations and color informations. Kale et al.[**29**] proposed a multi-modal biometric system using fingernail and finger knuckle, which used a second level wavelet decomposition as a segmentation technique regarding a nail area.

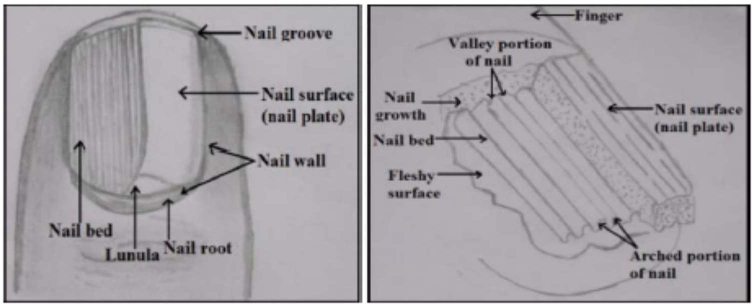

Figure 7. Nail information[22]

3.3. Gestures

Portable devices which have a touch panel and some sensors including a gyro, an acceleration sensor have been wide-spread for not only a business use but also a consumer use. Some smart-phones and tablets have a traditional biometric authentication feature, such as a fingerprint and face recognition, however, it would be more intuitive authentication task to touch the surface of the screen or to move the device, which users can do anytime. In this section, we describe "Touch Gesture Authentication" and "Hand Gesture Authentication" techniques which allows users not only to input some information to verify naturally, but also to be able to verify them continuously.

3.3.1 Touch Gesture

Sae-Bae et al.[**56**][**57**] investigated usefulness of multi-touch gestures as a biometric modality, which was based on trajectories of five fingers with some specified motion, such as a parallel, a close, an open, and a circular motion (see Fig. 8). Feng et al.[**20**] looked into an authentication method using touch informations during some simple touch gesture command, such as flick, pinch, rotate, and on. In addition, they analyzed finger motion data using a data globe which could obtain each finger's acceleration, direction information. Zhao et al.[**73**] proposed an authentication method which touch gesture feature was described as a graphic information. Furthermore, Servadda et al.[**59**] organized a database of touch-based authentication in order to compare various authentication algorithms.

3.3.2 Hand Gesture

Okumura et al.[**53**] studied a biometric authentication modality based on "Arm Sweep Action" with an acceleration sensor, which allowed users to input an information to verify by just shaking a device (see Fig. 9). Lee et al.[**40**] proposed gesture-based passwords which are included "Tap", "Flip and Tilt", and "Shake"

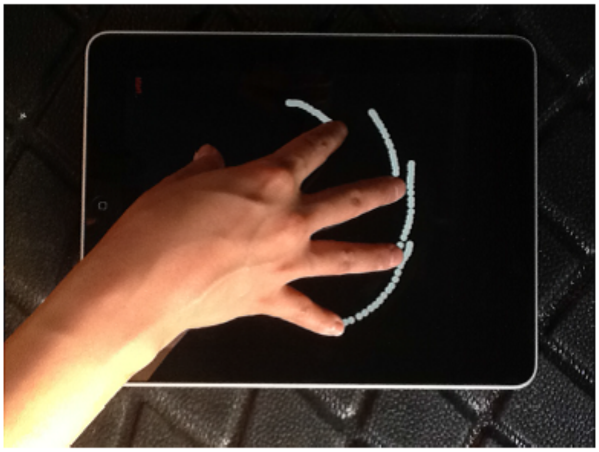

Figure 8. Finger touch gesture[**57**]

gestures. In this system, users can input a combination of gesture command instead of inputting a password. As a similar gesture-based authentication research, Liu et al.[**44**] discussed regarding different gestures, called gesture vocabulary, such as left, right, circle, rectangle, and on. Casanova et al.[**25**] evaluated gesture informations captured by a mobile phone using linear discriminant analysis.

4. Others

4.1. Cardiac Information(Heart Beat)

Cardiac information has been researched as one of prospective biometric modality for a continuous authentication system which can keep authentication as long as users wear or have a devices. Silva et al.[**63**] proposed an authentication system during key stroke with a pad can detect his/her electrocardiographic(ECG) (see Fig. 10). Matta et al.[**46**] also proposed ECG-based cardiac signal authentication system with a wearable device. Odinaka et al.[**52**] surveyed and evaluated various proposed ECG biometric recognition algorithms. Fatemian et al.[**19**] proposed a recognition method using not only ECG but also phonocardiogram(PCG) signal. Zhao et al.[**72**] discussed regarding liveness detection using ECG biometrics.

4.2. Stylometry

Stylometry is a statistical analysis regarding a literary style, which is also well-known as a continuous biometric authentication modality. Brocardo et al.[**7**] evaluated an authorship verification system for short messages using n-grams which is a contiguous sequence of n items from a given sequence of text. They can also introduced a novel approach using a presence or absence of n-grams, and their re-

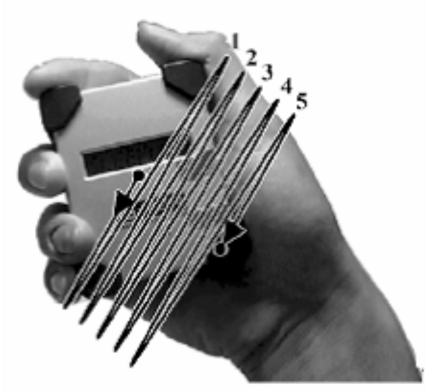

Figure 9. An example of a hand gesture[**53**]

lationship, which can reduce a processing time. Monaco et al.[**50**] evaluated their authentication system using written which students submitted to a server during taking on-line courses. Stuart et al.[**65**] analyzed which stylometry feature is effective to authorship verification.

Stewart et al.[**64**] proposed a combination authentication system which consists of a key stroke authentication technique and a stylometry technique. Fridman et al.[**21**] evaluated a multi-modal active authentication using not only stylometry features, but also web browsing behavior.

4.3. Body Odor

Recently, electronic noses have been utilized in various applications, such as quality control of foods and beverages, air protection, and medical applications, and there are some research papers regarding detection and analyzing human body odors. Gibbs[**24**] investigated the perception and acceptance about a body odor authentication, which experiment was conducted as a questionnair. According to the result, people seem to be unlikely to improve a body odor authentication performance, because the technique is uncommon and they cannot imagine the impact. However, he concluded if the technology become mature, a body odor authentication would be useful as a combination modality with the other biometric authentication modalities.

Wongchoosuk et al.[**67**][**68**] investigated which sensor is related to a specific gas is useful to distinguish persons. Furthermore, according to [**69**], they evaluated a body odor authentication using a networked electronic nose(E-nose), which has eight sensors, and they used Primary Component Analysis (PCA) as a classification method (see Fig. 11).

(a) Sensor pad applied to a keyboard (b) Interaction with the sensor pad, with the ECG shown on screen.

Figure 10. Cardiac authentication system[**63**]

5. Conclusion

In this paper, we introduced relatively newer prospective biometric authentication modalities in order to use as a supplemental modality or to realize a continuous authentication system. Additionally, some papers say that some modalities, such as eye movement, lip-motion, and cardiac information, are effective as a liveness detection technique, which can not only improve authentication accuracy in traditional biometric authentication systems, but also decrease risks regarding anti-spoofing attacks.

Actually, this paper cannot describe all of newer biometric authentication modalities, however, we hope this would be helpful as a pointer to state-of-the-art technologies.

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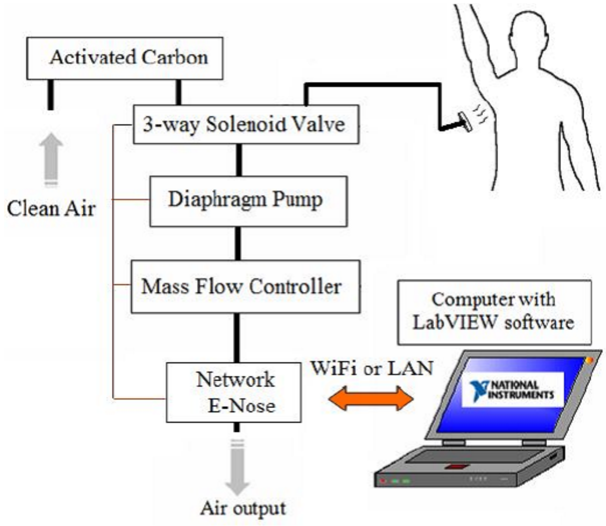

Figure 11. A body odor detection system[**69**]

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