NEC's Face Recognition Technology and Its Applications

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Abstract

With the recent rise in crime and terrorism the need for biometric personal authentication technology increases year by year. Face recognition technology has advantages not found in other biometric personal authentication technologies, e.g. a person does not have to take any special actions for authentication, and we human can identify the person visually with his or her face image. NEC's Information and Media Processing Labs participated in the Multiple Biometric Evaluation program, a biometrics technology evaluation program of the National Institute of Standards and Technology (NIST), USA, that was held from January to May 2010. NEC here achieved the highest recognition performance among the participating organizations, with the highest identification rate of 95% of 1.8 million persons and the lowest verification rate of 0.3%. This paper describes the face recognition technology developed by NEC and introduces the evaluation results by NIST as well as discussing actual applications of NEC's face recognition engine.

Keywords

face detection, face matching, biometric authentication, NeoFace

1. Introduction

With the advancement of the information society and the dissemination of network services, today has tended to increase the range of scenarios in which machine aided personal authentication is required. These include logging in to a computer or network, use of cash dispensers at bank ATMs, use of credit cards and entrance/exit of offices and apartment houses etc. The usual means of personal authentication in such situations are authentication by using something personal such as passwords and authentication by something you possess such as magnetic or IC cards. Nevertheless, these methods are not faultless, because the risk exists of forgetting or leaking the password or of the theft or counterfeiting of the card. Particularly, in the case of authentication by a password that you have memorized, it is hard to set and memorize several different passwords when the number of settings in which authentication is required increases.

On the other hand, biometric information is preferable as the authentication methods to passwords because there is no risk of forgetting [1] .

In addition, the face recognition technology has the following advantages:

(1) Since the input face image can be retained for record, it is easy to identify a person attempting misuse or causing false recognition. This feature is also expected to be an effective deterrent for discouraging abuse and misuse.

(2) Authentication is possible at a distance.

(3) A contactless input device can be used.

Below, we will describe in section 2, the face detection/matching techniques proposed by NEC and the results of evaluations of Multiple Biometric Grand Challenge (MBGC) [2] and Multiple Biometric Evaluation (MBE) [3] , which are biometrics technology evaluation programs of the U.S. National Institute of Standards and Technology (NIST) in section 3. Next, section 4 will introduce actual applications of NEC's face recognition technology and section 5 will discuss anticipated future issues of the face recognition technology and section 6 will give a summary of this paper.

2. Summary of Face Recognition Technology

Fig. 1 illustrates the face recognition process. The two face images subjected to matching are the registered image and the query image. First of all, face detection is applied to these images in order to determine the face area of each image. Then, facial feature point detection is applied to obtain the positions of distinctive feature points of the face such as the eyes, nose and corners of the mouth. Finally, the positions and sizes of the face areas are normalized according to the detected feature

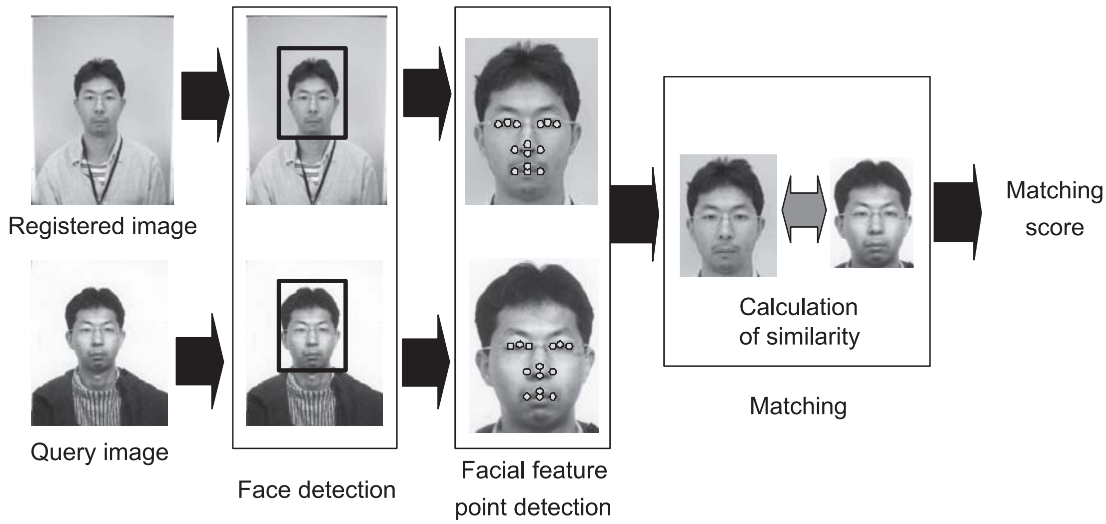

Fig. 1 Flow of face recognition.

point positions and matching is applied. In the following subsections, we will discuss the process performed at each step of the proposed technique.

2.1 Face Detection

Fig. 2 shows the process flow of the face detection technique using the Generalized Learning Vector Quantization (GLVQ). [4] First of all, to enable detection of faces of various locations and sizes, multi-resolution images are generated by reducing the image size by a certain ratio. Next, classification into two classes of face and non-face using GLVQ is applied to the multi-resolution images in order to generate face confidence maps. **Fig. 3** shows examples of the face and non-face images used in training of GLVQ. With each face confidence map described above, several face areas by labeling are merged to obtain the position of the face. Experiments have clarified that the accuracy of face detection algorithm using GLVQ is equivalent to or better than the Support Vector Machine (SVM) which is a conventional pattern classification method and that the face detection speed is much higher than SVM.

2.2 Facial Feature Point Detection

This section describes the process flow of the facial feature point detection technique using GLVQ and the face shape model, which is proposed as a reference material [5] .

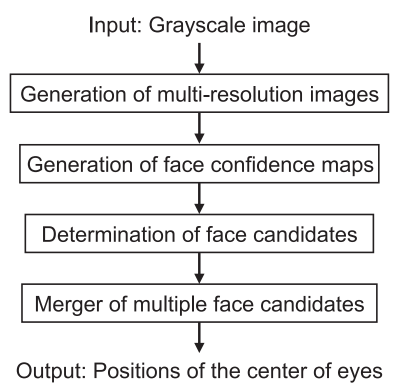

Fig. 2 Flow of face detection.

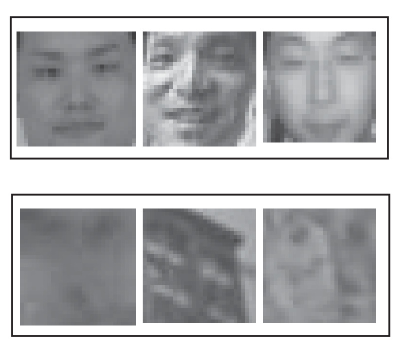

Fig. 3 Examples of face (upper row) and non-face (lower row) images.

The proposed technique is composed of two process stages, the "facial feature point candidate detection," which extracts the feature point candidates for each face feature point, such as the pupil or corners of the mouth, and the "optimization of positions using the face shape model," which determines the optimum position of the facial feature point from the extracted feature point candidates as shown in **Fig. 4** . In the first stage, the positions of facial feature points such as the pupils, subnose point and corners of the mouth are determined by generating confidence maps of each feature point using the GLVQ classifier that is constructed for each feature point and is capable of identifying whether each point is a facial or non-facial feature point. In the latter stage, the most suitable facial feature point positions are selected based on the facial feature point candidates obtained in the former stage and the face shape model, while determining abnormal values by minimum median estimation. This process enables highly accurate position detection even when information on face feature points is inadequate due to a change in illumination or blocking etc.

2.3 Face Matching

The query image and the registered image are not always shot under the same conditions. Changes in posture or illumination as well as facial expressions and ageing constitute important factors in matching performance deterioration. Since changes in posture and illumination are relatively easy to be modeled, we deal with these factors by applying the "perturbation space method" [6),7)] that generates images with various postures and illumination conditions from a single image. For the facial expressions and ageing that are difficult to be modeled, we apply the "discriminative multi-feature fusion method" that extracts features that are useful for personal identification from the large amount of face image data to reduce the performance deterioration. **Fig. 5** shows the process flow for generating images with various postures and illumination conditions from a single original image. The posture variation images are generated by estimating the 3D shape of the face and rendering it in various orientations. The illumination variation images are generated by using illumination models based on diffuse reflection model. For the "discriminative multi-feature fusion method," various kinds of features such as edge direction and local textures are extracted from the face image. The feature vectors are then projected to the feature space that remains unaffected by variation and is effective for personal identification. And then, the query image is compared with the registered images based on the distance between vectors in the feature space. In this way, by utilizing the two different methods, we can achieve highly accurate face matching that is able to cope with diverse variation factors.

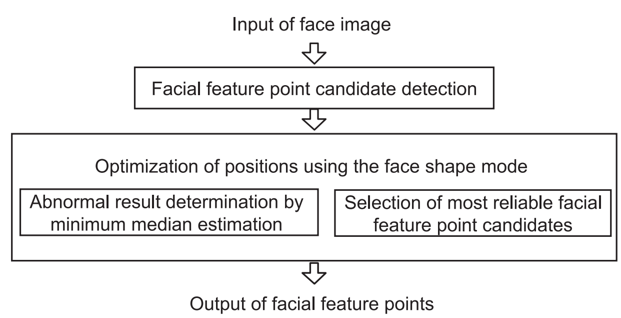

Fig. 4 Flow of facial feature point detection.

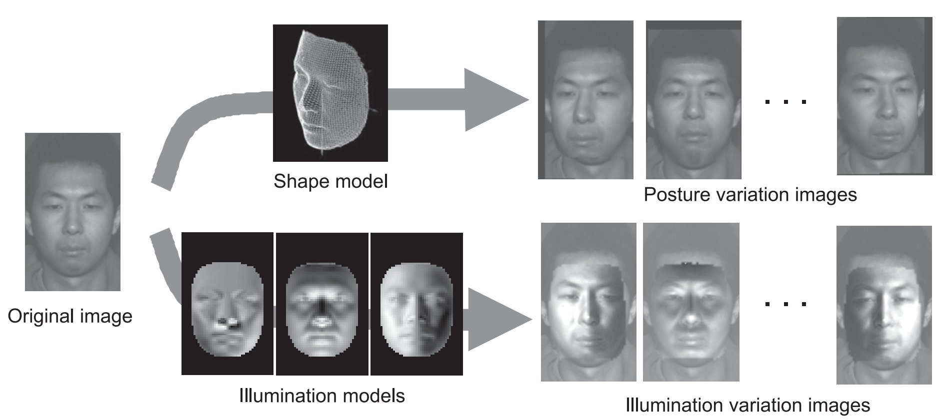

Fig. 5 Flow of generation of posture/illumination variation images.

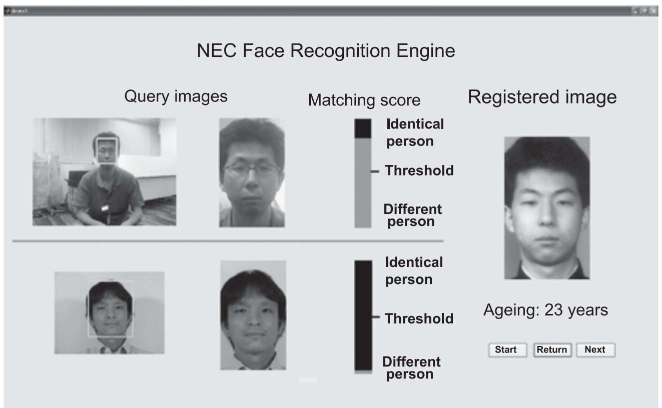

Fig. 6 Example of a matching result.

2.4 Example of a Matching Result

Fig. 6 shows an example of a matching result. The images on the left are the query images and the image on the right is the registered image. The person in the query image on the upper row is identical to the person shown as the registered image, and the person in the query image on the lower row is a different person. The matching scores are expressed in the bar graphs shown in the middle. A score of greater than the threshold means that the person in the query image is judged to be identical to the registered person and a score of less than the threshold means that the person is judged to be different. With the result for the upper query image, the shot person is judged to be identical to the registered person because the matching score is higher than the threshold. With the result for the lower query image, the shot person is judged to be different because the score is lower. This example shows that our identification engine is capable of correct matching in spite of about 23 years of ageing between the query image in the upper row and the registered image.

3. Performance Evaluation by NIST

Since the performance of a biometric personal authentication technology including face recognition can vary greatly depending on the shooting conditions of the input data, it can hardly be compared with other technologies unless the same data is used for the evaluation. The author et al. participated in NIST's biometrics technology evaluation programs MBGC (2008 to 2009) [2] and MBE (2010) [3] and our recognition engine obtained the highest evaluations in recognition performance and search speed compared with the engines of the other participating organizations.

The objective of MBGC was to compare and evaluate the face and iris recognition technologies based on set evaluation items in order to improve the technological abilities of the entire industry. The NEC Group participated in the still-image face recognition section and achieved the highest performance grade among the participants. The targets of the still-image face recognition section include face images shot with digital cameras that tend to improve the picture quality and face images reduced or compressed to a size usable in IC passports as well as images shot under severe conditions such as under insufficient illumination in halls or corridors and in direct sunlight outdoors. Even in the evaluations using face images shot under such severe conditions, the NEC engine achieved false non-match error rates (false rejection rate (FRR) at a false acceptance rate (FAR) of 0.1%) of 2% to 4%.

On the other hand, the objective of MBE was to evaluate the practical performance of immigration control systems and criminal career search systems. In this program, too, the NEC engine achieved high search accuracies, for example the top accuracy of 92% was achieved in the search from 1.6 million face images extracted from criminal records and the top accuracy of 95% in the search from 1.8 million face images used in visa applications. For the face authentication accuracies, too, with false non-match error rates of 4% with face images in criminal records and 0.3% with face images in visa applications. All of these evaluation results are much better than the performances of engines from the other participating organizations, witnessing thereby the superiority of the NEC face recognition technology.

4. Applications of Face Recognition Technology

According to the survey by the International Biometric Group, the total scale of the biometric market in 2009 was US $3.4 billion, in which face recognition has a share of 11.4% [8] . Five years later in 2014, the biometric market scale is expected to grow to US$9.4 billion. In Japan, the issue of IC passports containing IC chips with face information was started in March 2006. Submission of personal ID information such as face and fingerprints are mandatory for foreigners entering Japan, and the persons hit in the criminal career list may be denied entrance or taken into custody. The following subsections describe actual applications of NEC's face detection/recognition engine "NeoFace"[9)].

4.1 Universal Studio Japan ®

Universal Studio Japan introduced face recognition in the personal authentication system for its annual passport in November 2007. The owner of a passport holds it over the reader at the entrance and shows his or her face to the monitor screen and authentication completes in about a second. This system was introduced because of its ease of use for contactless authentications. In addition, the advantages of the system include the speeding up of annual passport issue procedures and the prevention of abuses even when the owner loses a passport.

4.2 Immigration Control System of Hong Kong Immigration Department

In the year 2007 the Hong Kong Immigration Department introduced an immigration gate control system that can recognize the faces of people and identify them automatically without them needing to get out of their vehicles. In Hong Kong, the personal ID information of all residents are already registered and handled with ID cards. In addition, the driver of vehicle can be identified from the vehicle number because every vehicle has one driver registered to it, so that a driver entering an immigration gate can be identified by reading the vehicle number at the gate. When the driver is identified as the identical person by means of face recognition, the immigration procedure completes and the gate opens. This system allows the control operations to complete smoothly because its advantage of contactless face recognition enables authentication without requiring that people get out of their vehicles.

5. Future Issues

Personal authentication is possible either by "cooperation-based authentication" with which the targeted persons are conscious of authentication and by "non-cooperation-based authentication" with which the target persons are not conscious of it. With the face recognition, an example of the former method is the person verification using a passport photo at the immigration desk, and that of the latter method is the personal identification for video surveillance. The former method has hitherto been the mainstream, but in the future, applications of the latter method are expected to increase as a result of the anticipated advances in face recognition technologies. In this section, we will describe the technical issues that must be overcome to deal with the non-cooperation-based authentication systems.

(1) Degradation of Matching Performance Due to Posture Variations

As described above, highly accurate matching is now becoming possible with frontal face images such as passport photos. However, even when the registered image is frontal, the authentication accuracy tends to drop considerably if the query image is shot from an obliquely upward angle. The main causes of this drop are the partial occlusion of the face and the three dimensional change of the face shape. At NEC, we have also been tackling R&D of the 2D/3D face matching method [10)] which matches the 3D face data with 2D face images and have achieved a very high matching performance in cases for which 3D shapes can be registered. In the future, we will also apply this technology in matching between 2D images to improve the performance with non-frontal face images.

(2) Degradation of Matching Performance Due to Low Image Resolution

When the face recognition technology is used for surveillance purposes, the matching performance tends to deteriorate because the resolution of the face image is often low due to its having been shot from a distance and the image itself is thereby compressed. In such a case, an extracted face image often lacks enough information for identifying person due to its low resolution, and the requisite radical improvement of the authentication performance is very difficult to achieve. In the future, we intend to solve this issue by adopting new approaches, for example by using several images for improving the resolution in cases for which the query image is on video.

6. Conclusion

In this article, we described our face recognition technology and discussed its actual applications and anticipated future issues. We intend to continue technical improvements by focusing on the issues discussed in section 5 to promote further dissemination and business deployments in this field.

*Results shown from the Multiple Biometric Evaluation 2010 do not constitute endorsement of any particular product by the U.S. Government.

References

1) Imaoka, “KAO NIYORU KOJIN NINSYO GIJUTSU TO OYO,” ITE Journal, Apr. 2010
2) P. J. Phillips: "MBGC Still Face Challenge Version 2 Preliminary Results," MBGC Workshop (2009)
3) P. J. Grother, G. W. Quinn and P. J. Phillips: “Report on the Evaluation of 2D Still-Image Face Recognition Algorithms”
4) Hosoi, Sato: "IPPANKA GAKUSYU BEKUTORU RYOSHIKA NIYORU KAO KENSYUTSU," SHINGAKU GIHO Vol.102, No.651, pp.47-52, 2003
5) Morishita, Imaoka: "IPPANKA GAKUSYU BEKUTORU RYOSHIKA TO KAO KEIJO MODERU NIYORU KAO TOKUCHOTEN KENSYUTSU", FIT2010
6) Inoue, Sakamoto, Sato: "BUBUN RYOIKI MACHINGU TO SETSUDO KUKANHO WO MOCHIITA KAOSYOGO," GAZO SENSHINGU SHINPOJIUMU, 9, pp.555-560 (2003)
7) Imaoka, Sato: "HANDAN BUNSEKI TO SETSUDO GAZOHO WO MOCHIITA KAO SYOGO ARUGORIZUMU," FIT2005 pp.31-32 (2005)
8) “Biometrics Market and Industry Report 2009-2014”, International Biometric Group 2008
9) http://www.nec.co.jp/soft/neoface/product/neoface.html
10) http://www.nec.co.jp/press/ja/0403/2203.html

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