Technologies for Improving the Speed and Accuracy of Fingerprint Identification Systems in Support of Public Bodies

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Abstract

In recent years, the technology of biometrics has been employed widely in the public domain, such as for citizen identification and election management solutions. NEC has long been conducting R&D for fingerprint matching technologies and for improving the speed and accuracy of large-scale solutions. This paper describes the proposed technological improvements that are required for the implementation of large-scale authentication solutions. It also discusses the strategies being adopted by NEC in support of further improvements. NEC's world leading biometric authentication technologies have been cultivated over many years and are contributing to the creation of a safer and more secure society.

Keywords

fingerprint identification, high-speed and high-accuracy matching, large-scale database, biometrics, multimodal

1. Introduction

The biometric identification technology is currently used widely, from consumer solutions such as entry/exit management and PC logins to national solutions such as for national ID numbering and electoral management systems. Of the biometric features, fingerprints have long been used as one of the core identification systems because of the high matching accuracy.

At NEC, we have dedicated over four decades to the R&D of biometric authentication technologies and have ranked top in major fingerprint identification accuracy tests[1]. We have also deployed the technology in a wide range of applications such as for the fingerprint matching systems of crime investigations[2] as well as large-scale authentication systems such as the Indian Unique ID (UID) system[3].

When operating authentication systems, the authentication processing time will not generally be a significant issue with relatively small scale matching targets such as the entry/exit management and PC login systems. However it may be so with the matching targets of large-scale systems such as for the national ID number system, which may be as large as in tens to hundreds of millions. In addition, thousands of inquiries are made every day and the total number of matching operations will therefore be enormous. As the increase in scale demands a need for enhanced searching accuracy among a larger number of targets, a higher level of matching accuracy is required. Therefore, with authentication systems with as large a scale as those supporting the public bodies, it is critical to establish a matching system that reduces the volume of computations without compromising the matching accuracy.

In this paper, we introduce a technology for improving the speed and accuracy of fingerprint matching operations for the support of large-scale authentication systems, we also discuss our attempts to implement matching with even higher speed and accuracy.

2. Fundamentals of Fingerprint Matching Technology

A fingerprint is composed of a striped pattern of friction ridges. Matching is usually performed by utilizing the ridge endings and ridge bifurcations of fingerprints as characteristic values (see **Fig. 1**). The relative directions and positions between minutiae are used as shown in **Fig. 2**. The matching technology based on minutiae makes basic matching operations possible.

However, the computational cost of minutia matching may be too high for the standard large-scale authentication systems.

Fig. 1 Ridge ending and ridge bifurcation of fingerprint.

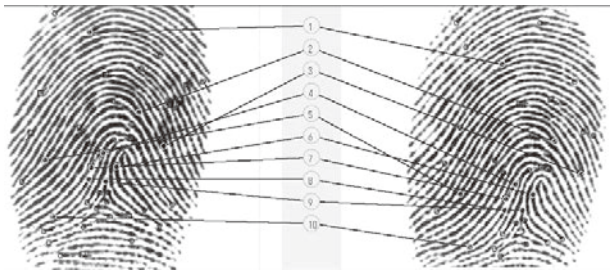

Fig. 2 An example of minutiae matching.

Furthermore, the matching accuracy generally drops as the matching speed increases. For matching at high speed while maintaining high accuracy, it is necessary to employ several speed/accuracy improvement technologies.

3. Large-Scale Fingerprint Matching Technology

3.1 Matching Technology in Large-scale Authentication Systems

Large-scale authentication systems implement high-speed, high-accuracy matching using the following technologies.

- Fingerprint segmentation
- Fast filtering using macro feature records
- Minutiae matching complexity improvement
- High-accuracy matching confirmation using multiple minutiae

3.2 Four-slap Fingerprint Segmentation

In principle the large-scale authentication systems collect all of the fingerprints of ten fingers, but collecting the fingerprint of each of the ten fingers takes time and labor. So the collection is usually performed with the "4-slap fingerprint" method, with which the fingerprints of the four fingers other than the left or right thumbs are collected at one time. This method makes it possible to collect the fingerprints of all of the ten fingers in three steps, once for the right four fingers, once for the left four fingers and once again for the two thumbs.

Fig. 3 Four-slap fingerprints and their segmentation.

Matching requires recognition and segmentation of each finger of the 4-slap fingerprints as shown in **Fig. 3**. However, the fingerprint collection operators of the national ID number system are often not accustomed to its operation so that in many cases optimum collections cannot be expected; e.g., for noisy images due to contamination on the collected surfaces and also for tilted images. For correct segmentation without causing authentication mistakes, even with such images, it is required to use an advanced authentication technology such as a noise removal algorithm. At NEC, we have developed a highly accurate segmentation technology based on advanced authentication, and we have been ranked top for accuracy in major segmentation accuracy tests[4].

3.3 High-speed Filtering Based on Macro Features

The minutia matching achieves a high accuracy but necessitates a large amount of processing computations. This highlights the importance of the filtering technology in reducing the number of candidates in the prior stage of the minutiae matching.

All of the fingerprints do not have the same pattern but exhibit different patterns, as shown in **Fig. 4**. If two fingerprints differ at the pattern level, they can be judged at a glance as belonging to different persons, without the necessity of comparing the minutiae. With fingerprints, many cases can be solved based on the macroscopic information (coarse features such as fingerprint patterns) without relying on the microscopic information, namely, minutiae.

Nevertheless, the prepared numbers of templates are not so abundant. Also fingerprints are often so similar that matching by a single finger causes the identification rate to be low, and does not work at all for fingerprint identification. High-speed filtering is therefore performed by using the macro information of all of the ten fingers. Highly efficient filtering is achieved by using the similarities between streams of ridges in addition to simple pattern information. This technology has succeeded in increasing the speed by a factor of ten to hundred.

3.4 Minutia Matching Complexity Improvement

The amount of computations is reduced by matching only the required number of fingerprints that are eligible for matching

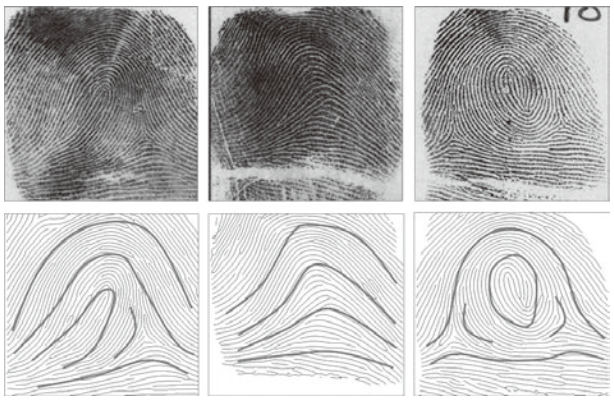

Fig. 4 Fingerprint patterns.

Fig. 5 Reducing computational cost by minutia pruning.

instead of matching all of the ten filtered candidate fingerprints. These fingerprints refer namely to the fingers with highly-reliable minutiae and those that show more similarities in the fingerprint patterns. As shown in **Fig. 5**, minimizing the area of minutia may increase the efficiency of the matching process further. The computational cost of minutia matching is roughly proportional to the product of the numbers of queries and target minutiae. Let us assume that 100 minutiae have to go through against 100 minutiae (100 × 100=10,000). It will be simply four times that of 50 minutiae against 50 minutiae (50 × 50=2,500). In this case, it can be expected that a matching process provided for 50 fingerprints of three fingers against 50 minutiae can achieve a higher accuracy than that of for 100 fingerprints of one finger against 100 minutiae. We achieve the best computation efficiency by optimally controlling the number of minutiae, numbers of fingers and fingers to be used for the matching process.

3.5 High-accuracy Matching Confirmation Using Multiple Templates

The matching process explained above should usually be enough for completing the matching process, but there may be a few cases when some false ones may be left in the matching results. Therefore, as the final step, we perform a final matching by using all of the available information. In this step, no limited minutia area is specified, which means that all minutiae are used, and moreover, the minutiae extracted by multiple methods are used (**Fig. 6**). There is no single universal feature extraction method that is effective for all fingerprints. The

Fig. 6 Risk reduction by adopting more than two minutia extraction methods.

suitable method varies depending on specific fingerprints. Therefore the steps shown in Fig. 6 can be an effective means of avoiding the risk of choosing an inappropriate extraction method.

As described above, the large-scale fingerprint identification process is composed of multiple advanced technologies and is not merely a matter of simple minutia extraction and matching technologies but also of the filtering and segmentation technologies using macroscopic information.

4. Aiming at Matching Technology with Higher Accuracy and Higher Speed

4.1 Improvement of Ridge Extraction Accuracy

The quality of fingerprint images varies greatly so that in some cases minutia extraction is not possible by any available method. Since improper minutia extraction results in reduced accuracy, improved minutia extraction is a critical factor for accurate identification.

At NEC, we are continually tackling improvements for the minutia extraction technologies such as for fingerprints that used to be difficult to make them into patterns. For example, in a case where the sweat gland pores are noticeable as shown in **Fig. 7**, the traditional minutia technology tends to recognize the pores as the valleys of ridges and often divides a fingerprint ridge into two parts. However, the latest ridge extraction technology is being given a higher technological level so that it may deal more accurately with such extraction fingerprint images that are not properly suitable for minutia extraction.

4.2 Advancement of Macro Information Filtering

We are also tackling the improvement of filtering accuracy

Fig. 7 Accuracy improvement of a fingerprint with noticeable sweat gland pores.

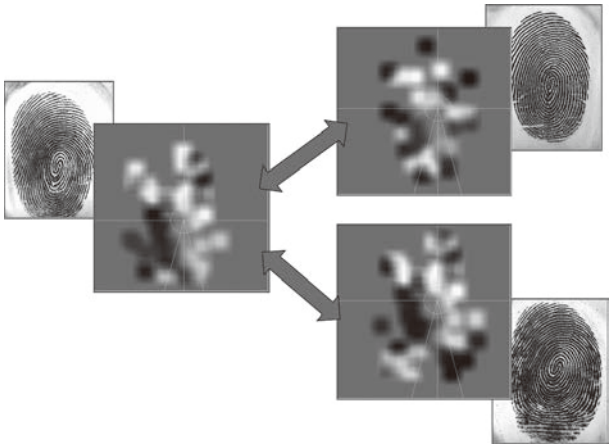

Fig. 8 Improved efficiency using the innovative filtering technology.

based on macroscopic information. The identification rate of fingerprints for which identification has not been possible with the traditional method based on the ridge direction has now been improved by using the minutiae orientation information as a means of filtering (**Fig. 8**). The latest identification rate improvement technology has made it possible to halve the number of matching devices without degrading the previous matching accuracy.

5. Conclusion

NEC has long been conducting R&D for fingerprint matching technologies as well as deploying a wide range of fingerprint identification solutions. The system needs a variety of methods depending on the needs of our clients, etc. In particular, large-scale solutions require technologies that are completely different in every aspect from those for small-scale solutions. We have implemented high-accuracy, high-efficiency matching systems based on many top-level key technologies and we are still endeavoring to develop effective authentication technologies that feature even higher speeds and accuracies. It is our top-level technological abilities that allow us to contribute to the creation of a safer and more secure society.

Reference

1) NEC ranks first in NIST fingerprint matching technology benchmark test, NEC Press Release, August 21, 2014, http://www.nec.com/en/press/201408/global_20140821_02.html
2) MIZOGUCHI Masanori, HARA Masanori: “Fingerprint/Palmprint Matching Identification Technology,” NEC Technical Journal, Vol. 5, No. 3, pp.18-22, 2010.10
3) SU Leiming, SAKAMOTO Shizuo: “Extremely-Large-Scale Biometric Authentication System - Its Practical Implementation,” NEC Technical Journal, Vol. 7, No. 2, pp.56-60, 2012.9
4) Bradford Ulery, Austin Hicklin, Craig Watson, Michael Indovina, Kayee Kwong: SlapSeg04 Analysis Report, 2005.3, http://www.nist.gov/itl/iad/ig/upload/ir_7209.pdf

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