Advanced Iris Recognition Using Fusion Techniques

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Abstract

Iris recognition is already beginning to penetrate the public sphere and has recently been adopted in smartphones, national ID systems, and border control. This paper outlines iris recognition technology in general and introduces the key elements of NEC's iris recognition technology — in particular, fusion matching technology which is playing a pivotal role in taking the precision of iris recognition to the next level. We will also review the results of the iris recognition evaluations conducted by the United States National Institute of Standards and Technology (NIST), which demonstrate unequivocally the superior precision of our technology. Finally, we will examine the latest trends in iris recognition technology.

Keywords

biometrics, iris, precision, NIST, IREX IX, living body detection, liveness, multimodal, fusion

1. Introduction

Biometrics is fast becoming the predominant method for individual identification and authentication in modern society. Starting with fingerprint recognition several decades ago, biometrics has evolved over the years to encompass other recognition modalities that take advantage of the unique characteristics of other parts of the body such as the face, the veins, and so on. Most of these newer modalities have been put into practical use. One of the most recent is iris recognition.

The human iris is a thin membrane on the interior of the eyeball, situated between the cornea and crystalline. It acts to control the amount of light entering the eye through the pupil by opening and closing. The pattern of the smooth muscle which dilates the diameter of the pupil is determined by the amount of melanin pigment. Now it is possible to use this pattern to identify an individual.

When and who first proposed the concept to identify an individual using the iris pattern differs from one account to another. The generally accepted account is that it was first proposed by ophthalmologist Frank Burch in 1936[1].

Iris recognition as we know it today first gained prominence when Cambridge professor John Daugman developed and patented an algorithm to automate identification of the human iris in 1994[2]. The precision of iris recognition became widely known a decade later when the results of 200 billion iris cross-comparisons were released by the University of Cambridge Computer Laboratory in June 2005[3]. Since then, many vendors around the world have deployed solutions based on this patent. At NEC, we developed our own original algorithm, using it as the basis for research and development, and ultimately began releasing iris recognition products that have set world standards for precision and reliability.

When the iris is scanned using visible light, a strong reflection is created by the cornea and there is a significant difference in corneal thickness between races. When near infrared light is used instead, the differences between races can be suppressed, making it possible to obtain a relatively stable amount of information. Because near infrared scanning can also suppress light reflections, nearly all of today's iris recognition systems use near infrared light for scanning.

Besides having a distinct pattern unique to each individual, the iris is protected by the cornea, making it one of the components of the human body that is least likely to be damaged. The pattern of the iris is usually stabilized at some point in the first six months after birth and generally remains unchanged for the rest of the individual's life. Moreover, iris patterns are completely random; there is no similarity between identical twins and even between the same person's left and right eyes. This all makes iris recognition an excellent modality for biometrics.

2. Principles of Iris Recognition

The process of iris recognition begins by locating the position of the iris. This is done by identifying the inner and outer boundaries of the iris shown in **Fig. 1**. In other words, the area composing the donut-shaped ring, which corresponds to the iris, is located. The donut-shaped ring may not always be a perfect circle because distortion sometimes occurs, in which case it is treated as an ellipse to enhance precision.

Next, the donut-shaped iris area is divided into sectors as shown in **Fig. 2**. The luminance of the iris in each microspace is converted into numerals. By encoding the variations of numerals in adjacent microspaces, the system generates the feature values.

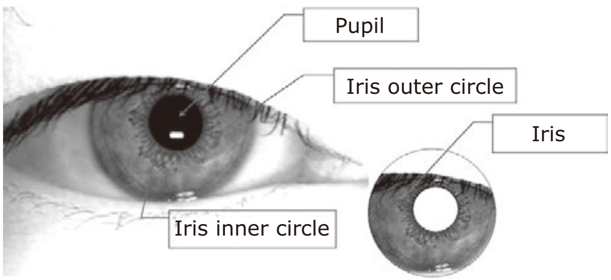

Fig. 1 Localization of the iris area.

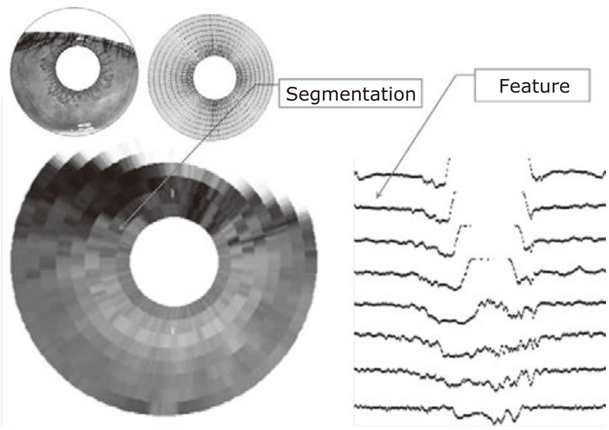

Fig. 2 Generation of iris feature values.

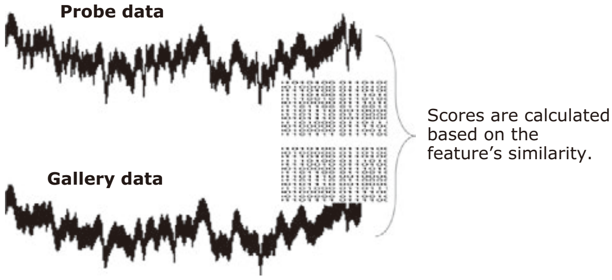

Fig. 3 Iris matching.

Finally, the features values generated as shown in **Fig. 3** are compared and collated to calculate the degree of similarity.

3. NEC's Iris Recognition

NEC started researching and developing iris recognition technology in 2007. Two years later in 2009 we successfully completed our first algorithm and obtained a patent for it. In 2014, as biometrics entered the mainstream, we ramped up research, increasing the number of researchers assigned to this field in an effort accelerate improvements in precision and performance. Later, we participated in Iris Exchange (IREX) IX evaluations where our algorithm was judged to have the highest matching accuracy[4]. Below, we discuss the various elements that contributed to this achievement.

3.1 Taking advantage of image recognition technology derived from our experience in fingerprint recognition technology

When we began our research into iris recognition technology, the core of our development team was drawn from long-time researchers with years of experience in the development of fingerprint recognition technology. As different as the eyes and fingers may seem, fingerprint recognition and iris recognition are actually quite similar in terms of the extraction of feature quantity from images. Thus, the image recognition technology we had developed for fingerprint recognition could quite easily be converted for use in iris recognition, enabling us to quickly build up a powerful, high-precision iris recognition system without starting from scratch (**Fig. 4**).

3.2 Multi-algorithm feature extraction fusion matching technology

A form of biometric technology known as fusion matching has proven extremely effective at improving the precision of iris recognition. Fusion matching technology uses multiple algorithms to extract and collate

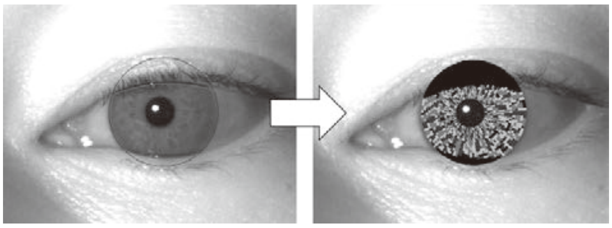

Fig. 4 NEC's iris detection and feature extraction.

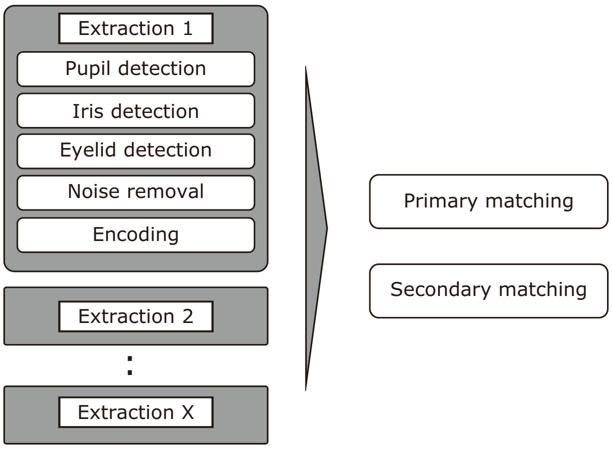

Fig. 5 Iris fusion matching technology.

features, synthesizing the results to improve precision. It is generally understood that the more variations there in the features being examined, the more effective fusion matching becomes. In order to construct multiple feature extraction algorithms, internal processing and other operations related to iris recognition are fractionalized as shown in **Fig. 5**. To increase combination patterns, we developed multiple algorithms for each internal process. This enabled us to build numerous feature extraction patterns in a short period of time, thereby contributing to the improvement of precision.

3.3 High-speed matching technology based on CPU optimization

Matching precision and speed exist in a relationship that can only be described as a trade-off. The more times matching is executed, the greater the level of fusion, and the higher the precision of the results. Increasing speed would normally require reducing the number of times matching is executed, thereby reducing accuracy. We got around this by optimizing the software to maximize the potential of the CPU. To accomplish this, we asked for help from a team at NEC Central Research Laboratories who specialized in this field. We succeeded in significantly improving processing performance by using vectorization to perform optimization. By transforming loops to vector operations, this allowed to execute fusion matching many times at very high speed.

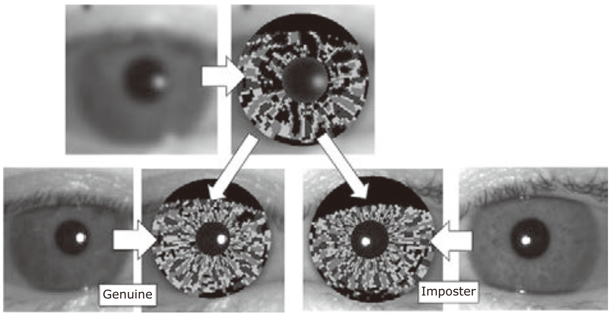

Fig. 6 Matching of out-of-focus iris images.

3.4 Fine-tuning the fusion matching technology

Although we have incorporated many feature extraction algorithms, without effective combinations, the effectiveness of fusion matching would be limited. NEC owns time-tested fusion matching optimization technology that builds on our proven fingerprint recognition technology. Application of this technology enabled us to achieve optimal combinations for fusion matching in a short period of time.

3.5 Issues with iris recognition

There are a number of issues unique to iris recognition that are not seen in other biometric modalities. One of these is the potential for false positives due to out-of-focus images. Because iris recognition uses iris patterns as they appear in the captured image to extract feature values, out-of-focus images can result in high scores even when the images are of different individuals. NEC has developed a new technology that can match the correct individual at high precision while suppressing the acceptance rate of other individuals due to out-of-focus images (**Fig. 6**).

4. Iris Recognition Applications

Biometrics is becoming increasingly common in our day to day lives. Due to its unique characteristics, the scenarios where iris recognition can be used are distinct from other biometric modalities.

Iris recognition is generally not used for any negative identification applications. For example, since the iris pattern does not linger on an object at a crime scene, it is not used for criminal investigation. Nor is it used for ordinary surveillance. The area of the iris is so small that it does not provide the level of resolution needed to obtain iris information from images shot with a large camera-to-subject distance at a standard angle of view. Moreover, since infrared light is used to scan the iris, it is difficult to capture the face and iris simultaneously.

Iris recognition really comes into its own in positive identification applications. The rate of false positives is very low and changes in the weather or the physical state of the human body have no effect. This makes it ideal for applications such as payment verification, as well as in cases where other modalities are less effective such as when parts of the body other than the eyes are covered — for instance, when medical personnel wear masks, gloves, and caps, when a protective gear is worn at the entrance to a critical facility, or when coal miners are covered with dust.

Iris recognition is also suitable for applications in multimodal systems that use combinations of biometric modalities (national identification system, for example). For instance, in India's national identification system in India — called Aadhaar — it is mandatory that citizens register their bioinformation of fingerprints, faces, and irises when they register their unique ID numbers. The false acceptance rate of Aadhaar required less than one of 100-billionth.Such high precision is difficult to achieve with a single modality. But by combining iris, fingerprint, and face recognition, the Aadhaar system is able to achieve this extraordinary level of precision.

5. Prospect of Iris Recognition

The fact that iris recognition requires a dedicated device to scan the iris has slowed its popular acceptance. However, the optical components of the device have exponentially evolved in these 10 years, lowering the threshold of introduction.

Since the area of the iris is relatively small, a VGA (640 x 480 pixels) image should be sufficient. Ideally, however, the iris should be scanned at a resolution of about 500 dpi. This requires the use of a lens with a long focal distance when the subject is away from the camera. This results in a narrow angle of view, which makes it difficult to capture an image of a moving person. Fast shutter speeds can also be problematic in cases where the amount of infrared light is small, making it necessary to reduce the aperture value. This results in a shallow depth of field, restricting the usable in-focus distance to a small range.

Today's most usable iris camera uses face recognition and iris shooting in combination. The position of the face can be located instantaneously inside the camera. Then, because the lens used to capture the iris is movable, it can be moved to the position of the iris, dispensing with the angle-of-view problem. Theoretically, the iris can be shot from a relatively long distance with this type of camera. Cameras that can capture images at up to a meter from the subject are already available on the market and have been put into practical use. As this type of camera becomes more affordable and more compact, applications for iris recognition can be expected to expand.

NEC will continue its pursuit of high-speed, high-precision iris recognition technology. Through the use of larger-scale, more accurate recognition technology, we will keep our commitment to contributing to the achievement of safe and secure society.

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