Iris Recognition: A General Overview

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Abstract

This article reviewed the literature regarding iris recognition. Theprocess of iris recognition is discussed in the context of the mathematical principles that underlie this procedure. Possible applications for iris recognition are explored.

Introduction

Iris recognition is not a new idea but has only been available in practical application for the last 10 to 15 years. This idea has been featured in many science fiction movies but until recently was just a theoretical concept. Iris recognition is used for security purposes and is an almost foolproof entry-level access security means because of its ability to readily identify false irises (Henahan, 2002, ¶ 8). It has not been widely used because of the cost, but has applications that are ever increasing. Iris recognition will be a viable option for any security system in the future.

Iris recognition is a biometric that depends on the uniqueness of the iris. The iris is a unique organ that is composed of pigmented vessels and ligaments forming unique linear marks, slight ridges, grooves, furrows, vasculature, and other similar features and marks (Daugman, 2003a). Comparing more features of the iris increases the likelihood of uniqueness. Since more features are being measured, it is less probable for two irises to match. Another benefit of using the iris is its stability. The iris remains stable for a lifetime because it is not subjected to the environment, as it is protected by the cornea and aqueous humor.

The process of iris recognition is complex. It begins by scanning a person's iris (Henahan, 2002, ¶ 6). The individual stares into a camera for at least a second allowing the camera to scan their iris. An algorithm processes the digital image created by the camera to locate the iris. Once the iris has been located, another algorithm encodes the iris into a phase code that is the 2048-bit binary representation of an iris (Daugman, 2003b). The phase code is then compared with a database of phase codes looking for a match. On a 300 MHz Sun Microsystems processor more than 100,000 iris codes can be compared in a second (Daugman, 2003a). In a matter of a few seconds an individual can have his/her eyes scanned and matched to an iris code in a database identifying the individual.

The Uniqueness of the Iris

How can we be sure the iris is unique? In analyzing the iris there must be bits of an iris phase code that are statistically independent. Statistically independent means an event's likelihood of occurrence is equally probable regardless of the outcome of a given event (Larsen & Marx, 2001). The statistical independence of an iris can be determined by using the Boolean Exclusive-Or, XOR, and AND operators on the iris phase bits of any two patterns (Daugman, 2003b). XOR is a bit comparison operator that that will return 0 when comparing like bits and otherwise returns 1. AND is also a bit comparison operator that will return 1 only when comparing bits that are both 1. The XOR operation shows how the two iris patterns differ, and the AND operation eliminates the effects of background noise in the image. The combination of the XOR operator with the AND operator to normalize the result produces a fractional Hamming distance.

A fractional Hamming distance is used to quantify the difference between iris patterns. The Hamming distance of two vectors is the number of components in which the vectors differ in a particular vector space (Gallian, 2002). In this instance, the fractional Hamming distance will always be between 0 and 1. For iris patterns, the Hamming distance should theoretically be 0.500 because a bit has an equally likely chance of being 0 or 1 (Daugman, 2003b). Dr. John Daugman, a professor at Cambridge University, analyzed the Hamming distances by comparing over 4250 iris images. He found the distribution of Hamming distances to be a perfect binomial distribution with a mean of 0.499 and a standard deviation of 0.0317. A binomial distribution is a model based on a series of trials that have two possible outcomes (Larsen & Marx, 2001). The mean is the average of all measured values, while the standard deviation is amount that the values tend to vary from the mean. The observed maximum value was 0.664, and the observed minimum value was 0.334. This means that it highly unlikely for two different irises to agree in more than two thirds of their phase bits. By a simple calculation, the degrees-of-freedom of the distribution is 249. This demonstrates that of the 2048 bits, only a small number are mutually independent due to corresponding radial components that exist within an iris. These findings demonstrate the uniqueness of an iris using the Hamming distance as a measurement.

Are the irises of two people with the same genetic makeup distinguishable? This is an important question because it would demonstrate a possible pitfall in this biometric. This condition hinders DNA testing because identical twins, twins from the same embryo, yield the same results in a DNA test. Any given person has a genetically identical pair of left and right irises that can be compared (Daugman & Downing, 2001). In a similar analysis done by Daugman, 648 iris images from 324 people were subjected to the same conditions used to render a Hamming distance (2004). The mean and standard deviation for this analysis were 0.497 and 0.031, respectively. This study was repeated with the irises from identical twins and yielded a similar result. These studies show that an individual has two unique irises, and a pair of twins has four unique irises. Thus, an iris image is independent of an identical genetic makeup.

Locating the Iris

The iris is captured in an image by a camera. The camera needs to be able to photograph a picture in the 700 to 900 nanometers range so that it will not be detected by the person's iris during imaging (Daugman, 2003b). The camera may or may not have a wide-angle lens yielding a higher resolution, but in either case a mirror is used to utilize feedback for the image. These conditions must be met in order for the iris image to have the necessary 50-pixel minimum size of the iris radius.

Once the image of the iris is obtained, the iris needs to be located within the image. There are three variables within the image that are needed to fully locate the iris: the center coordinates, the iris radius, and the pupil radius (Daugman, 2003b). An algorithm determines the maximum contour integral derivatives using the three variables to define a path of contour integration for each of the variables. The complex analysis of the algorithm finds the contour paths defining the outer and inner circumferences of the iris. Statistical estimation changes the circular paths of the integral derivatives to arc-shaped paths that best fit both iris boundaries.

Encoding the Iris Image

Once the iris has been located, it must be encoded into an iris phase code. The iris image is encoded using two-dimensional Gabor wavelets (Daugman, 2003a). A wavelet is a correspondence to a signal in waveform of a finite length (Wavelet, 2005, ¶ 2). A wavelet transform may be used to complile raw data, like an image, and encode it into a compressed file. This application can be used directly in iris recognition for the encoding process. Daugman uses wavelets to create more than two thousand phase bits from a raw image in a dimensionless polar coordinate system (2004). The system is dimensionless to allow for more flexibility when comparing iris images of different size and quality. Polar coordinates are used because they represent these curves in a simpler way compared to other coordinate systems. Each bit is determined by its phasor coordinates to minimize the impacts of errors. Masking bits are also used to minimize the effects of eyelids, eyelashes, contacts, and other hindrances. The use of phase coordinates makes the encoding resilient to out-of-focus images because it prevents all out-of-focus irises from looking similar, as is the case with facial recognition.

Once the iris has been encoded, it can then be compared to any other iris encoding. With comparison algorithms, an iris mapping can be compared to more than 100,000 different irises within a second on a 300 MHz Sun workstation (Daugman, 2004). As computer speeds increase, the number of comparisons will only increase and make the process faster. The process is completed and a match is found in only a matter of seconds, making it very efficient.

Matching Iris Codes

The question remains, what constitutes a match? Specifically, the number of iris phase bits that need to correspond for a match must be determined (Daugman, 2004). The number of phase bits required for a match is decided based on the specific application regarding how many irises need to be compared. Irises need to be matched regardless of their size, position, or orientation. This is accomplished by placing the image into a dimensionless polar coordinate system. Since the inner to outer boundary range of the iris is defined to be the unit interval, the pupil dilation and location becomes invariant. The criteria used to decide if iris codes match is called the Hamming distance criterion, which is the integration of the density function raised to the power of the number of independent tests. A density function is the sum of all probabilities of a possible outcome given a random variable, which in this case is the Hamming distance of an iris phase code. A smaller criterion results in an exponentially decreasing chance of having a false match. This allows the strictness of matching irises to easily change for the particular application. A Hamming distance criterion of 0.26 gives the odds of a false match of 1 in 10 trillion, while a criterion of 0.32 gives the odds of 1 in 26 million. The numeric values of 0.26 and 0.32 represent the fractional amount that two iris codes can differ while still being considered a match in their respective instances.

Applications for Iris Recognition

Iris recognition has tremendous potential for security in any field. The iris is extremely unique and cannot be artificially impersonated by a photograph (Daugman, 2003). This enables security to be able to restrict access to specific individuals. An iris is an internal organ making it immune to environmental effects. Since an iris does not change over the course of a lifetime, once an iris is encoded it does not need to be updated. The only drawback to iris recognition as a security installment is its price, which will only decrease as it becomes more widely used.

A recent application of iris recognition has been in the transportation industry, most notably airline travel. The security advantages given by iris recognition software have a strong potential to fix problems in transportation (Breault, 2005). Its most widely publicized use is in airport security. IBM and the Schiphol Group engaged in a joint venture to create a product that uses iris recognition to allow passengers to bypass airport security (IBM, 2002, ¶ 5). This product is already being used in Amsterdam. A similar product has been installed in London's Heathrow, New York's JFK, and Washington's Dulles airports (Airport, 2002, ¶ 2 & 3). These machines expedite the process of passengers going through airport security, allowing the airports to run more efficiently. Iris recognition is also used for immigration clearance, airline crew security clearance, airport employee access to restricted areas, and as means of screening arriving passengers for a list of expelled persons from a nation (Daugman, 2005). This technology is in place in the United States, Great Britain, Germany, Canada, Japan, Italy, and the United Arab Emirates.

Conclusion

Iris recognition has proven to be a very useful and versatile security measure. It is a quick and accurate way of identifying an individual with no room for human error. Iris recognition is widely used in the transportation industry and can have many applications in other fields where security is necessary. Its use has been successful with little to no exception, and iris recognition will prove to be a widely used security measure in the future.

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