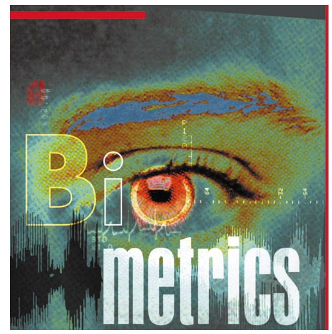
COVER FEATURE

An Iris Biometric System for Public and Personal Use



The human iris promises to deliver a level of uniqueness to identification applications that other biometrics cannot match. The authors describe a working system used in the UK and in pilot projects worldwide.

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Much work in the emerging field of biometrics has focused on identification applications. Biometrics offers the means to identify individuals without requiring that they carry ID cards and badges or memorize passwords. A leading concern in the development of such applications, however, is how to avoid rejecting valid users or approving impostors. The iris may provide a solution by offering a much more discriminating biometric than fingerprint or face recognition.

We have designed and implemented an iris biometric system that can function as an extremely reliable means for personal electronic identification. Further, our system solves problems associated with public-use devices such as automated teller machines, where habituated use is not the norm. The system also addresses personal-use devices, such as home banking, and other Internet and network applications, such as secure business logons.

THE IRIS AS A BIOMETRIC

The highly randomized appearance of the iris makes its use as a biometric well recognized.[1-3] Its suitability as an exceptionally accurate biometric derives from its

- extremely data-rich physical structure,
- genetic independence—no two eyes are the same,
- stability over time, and
- physical protection by a transparent window (the cornea) that does not inhibit external viewability.

Conversion of an iris image into a numeric code that can be easily manipulated is essential to its use. This process, developed by John Daugman, permits efficient comparison of irises.[2-4] Computing *iris codes* requires good-quality iris images that have the customer's iris in focus and properly positioned. Once the image has been obtained, an *iris code* is computed based on information from a set of Gabor wavelets.[2,5] These wavelets are specialized filter banks that extract information from a signal at a variety of locations and scales. The filters are members of a family of functions, developed by Dennis Gabor in 1946, that optimizes the resolution in both the spatial and the frequency domain. The iris code is calculated using eight circular bands that have been adjusted to conform to the iris and pupil boundaries, as shown in Figure 1.

Iris codes derived from this process are compared with previously generated iris codes. The difference between two iris codes is expressed as the fraction of mismatched bits, termed a Hamming distance.[2,4] For two identical iris codes, the HD is zero; for two perfectly unmatched iris codes, the HD is 1. For different irises, the average HD is about 0.5, which indicates a 50 percent difference in the codes. For two different images from the same iris, the HD ranges from approximately 0.05 to 0.1, a variation that includes contributions from video noise as well as variations in the position of the user's eye with respect to imaging optics. Generally, an HD threshold of 0.32 can reliably differentiate authentic users from impostors.

PUBLIC VERSUS PERSONAL USE

The use of a public device, such as an automated teller machine, involves many issues best solved by a system that requires minimal cooperation, training, and habituation. At an ATM, the customer expects to be able to approach, provide identification, and be recognized. In our public-use device, the customer need only gaze in the direction of the optical unit. The user can stand anywhere within a three-dimensional volume bounded by a 15- to 30-inch range and a 60-degree vertical and 46-degree horizontal capture range.

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The system automatically locates the subject's eyes, takes a high-resolution video image of one eye, computes an iris code, and validates it by comparing the code to the customer's previously enrolled iris code.

A desktop device has a different set of constraints, with cost probably most important for widespread deployment. Thus, in the private channel, most automated features must be removed. To use the device, the user performs more cooperative actions, such as aiming and focusing a camera. The device also provides feedback to aid the user in aligning the camera and to indicate a successful alignment.

Public-use system

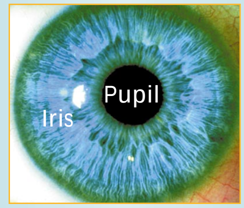
The components of the public-use system, shown in Figure 2, include

- a stereo, wide-field-of-view (WFOV) camera pair and associated processing for finding the face and eye of a user in a 3D volume;
- a narrow-field-of-view (NFOV) camera with a computer-controlled focus mechanism for obtaining a close-up image of the user's iris;
- a computer-controlled pan-tilt mirror used to direct the NFOV camera's optical axis to image one of the user's eyes;
- infrared illuminators used to illuminate the acquisition volume;
- a processing platform containing the computers, electronics, and software necessary to complete the system; and
- a gaze director to orient the user for proper positioning with respect to the WFOV and NFOV cameras.

Figure 3 shows a solid model of the imaging components' packaging implementation. The pods on either side house nonvisible infrared light-emitting diode illuminators whose wavelength is about the same as a TV remote-control device. The center LED is the *gaze director* used to focus the customer's attention in the proper direction. An optical window passes the illuminator wavelengths, prevents visible light from entering the cameras, and also prevents users from seeing the internal components.

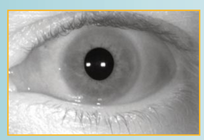
The WFOV subsystem uses custom real-time image-processing hardware for stereo-image generation. These images provide a depth map of the customer's head and eyes. A face-template-matching algorithm determines the position of the subject's eyes in image space. The eye position and distance to the eye region are sent to a controller, which adjusts a pan-tilt mirror and a fixed-focal-length lens so that the NFOV camera captures a high-resolution, centered image that contains the customer's right or left eye.[6] The system then processes the iris image to compute an iris code[2,4] for comparison to an enrollment

Iris identification public-use system

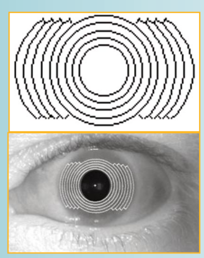


1. A user stands one to three feet from the system, which contains three standard video cameras.

2. Two wide-angle cameras image the user's torso. Using technology developed specifically for this application, the system determines the position of the eyes.



3. A third camera focuses on an eye and captures a single black-and-white digital image. Successful identification can be made through eyeglasses and contact lenses, and at night. If needed, the picture is rotated to compensate for a tilted head.



4. The system uses a circular grid as a guide to encode the pattern in the iris.

5. The grid is overlaid on the eye's image. The system looks at the patterns of light and dark iris areas and their distribution inside the grid, then generates a 512-byte human bar code for that person. The system will perform properly even if eyelashes or the eyelid obscure part of the grid.

6. The system checks the bar code against the version stored in a computer database. The entire process—from first picture to verification—takes about two seconds.

Figure 1. Iris identification process. The system captures a digital image of one eye, encodes its iris pattern, then matches that file against the file stored in the database for that individual.

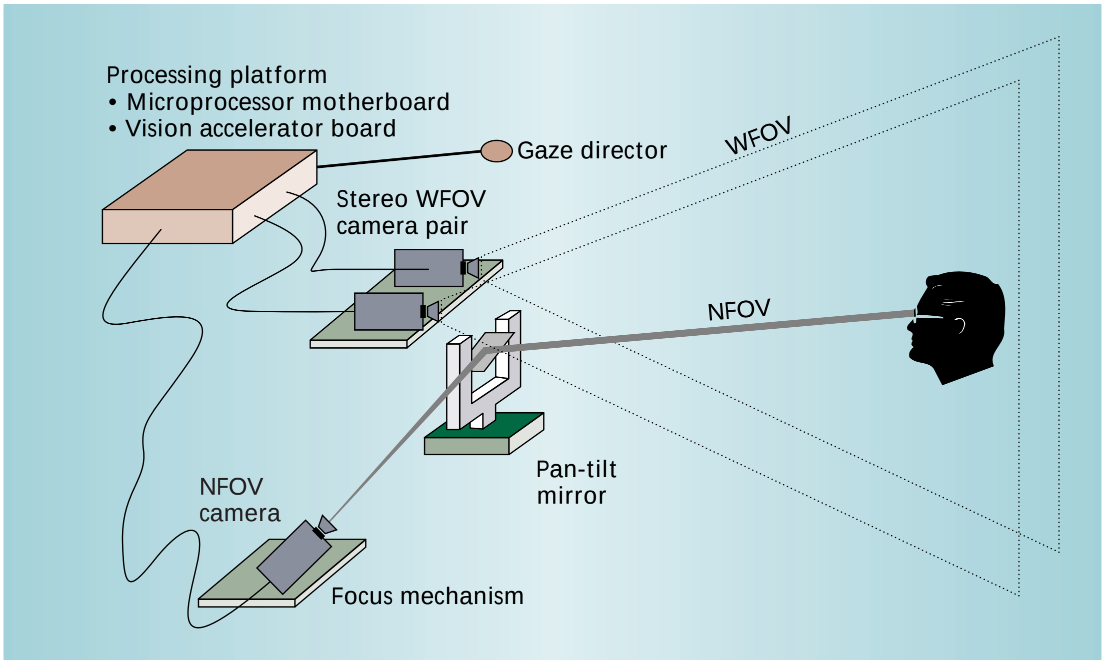


Figure 2. The public-use multiple-camera system for correctly positioning and imaging a subject's iris.

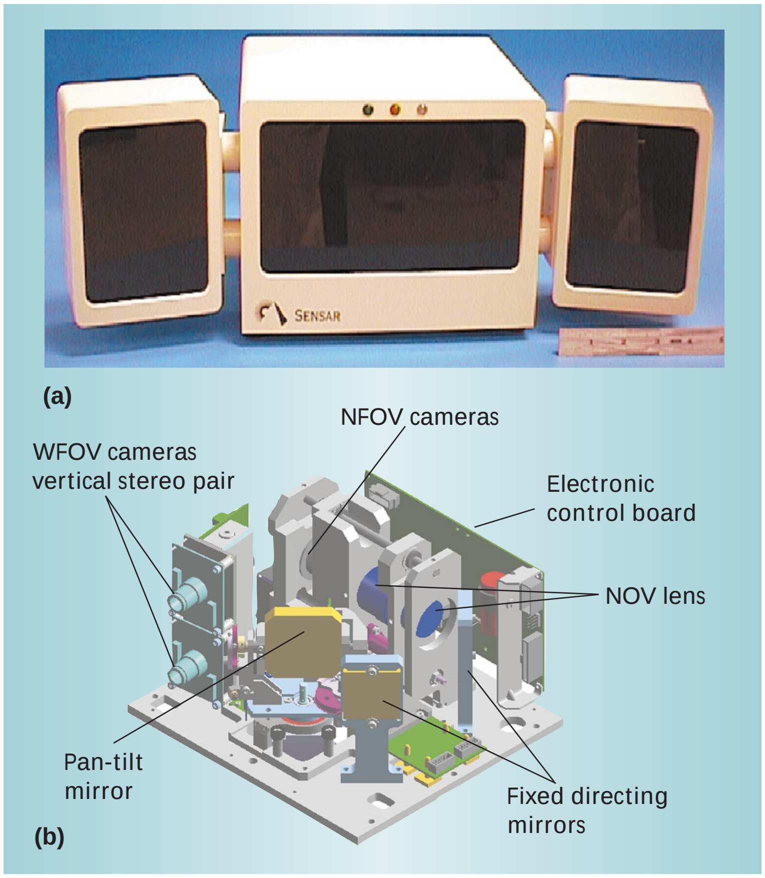


Figure 3. The public-use optical platform, showing (a) left and right illuminator pods, gaze director, and optical filter; and (b) a solid model of the platform's internal components.

iris code stored in a database. Iris pixels captured in this process have a resolution of approximately 50 microns. The overall operation—finding the face, finding an eye, computing an iris code, and determining a match—requires an average processing time of about 2.5 seconds.

Personal-use system

The personal-use system consists of a handheld digital camera connected through a Universal PC Serial Bus or parallel port to a PC. The user must manually position the camera three to four inches in front of the eye. The optical-alignment process uses parallax between an LED and an aperture to visually indicate misalignment in the angular and distance dimensions. The user centers the LED within the aperture that superimposes the user's line of sight with the camera's optical axis. Proper focus is achieved by moving the camera in and out until the LED just fills the aperture. At that point, the iris is in focus and properly centered. Figure 4 shows the alignment process.

The final element in image acquisition is a real-time quality measure that detects a well-focused, well-centered iris. It provides repeatable results by removing the user's judgment from the image acquisition process. As soon as the image quality measure is satisfied, the system provides audio feedback that indicates the completion of image acquisition. Finally, the system compresses the image for rapid transmission to a central verification server, which uncompresses the data, extracts the iris code, and matches it against a stored iris code, as shown in Figure 5.

PERFORMANCE

We used both statistical analysis and field trials to gauge the effectiveness of our system.

Identification performance

The false-reject rate is the error rate at which the system rejects a true authentic, such as an individual who claims to be himself or herself. Conversely, the false-accept rate is the error rate at which the system accepts a false authentic, such as an impostor claiming to be someone else. These error rates interrelate. Being more liberal in accepting people will generally allow more people—both authentics and impostors—into the system. Being stricter in accepting will reject more people, both authentics and impostors.

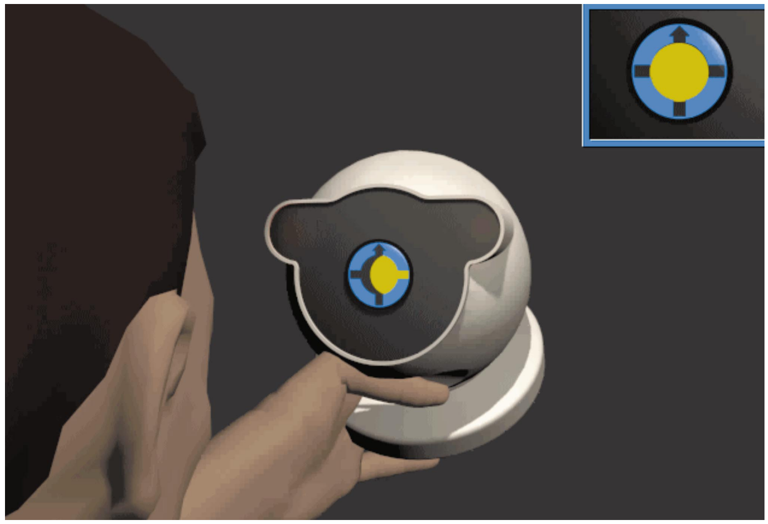


Figure 4. Personal-use camera alignment. The user manually positions the camera so that the device's LED centers within the aperture that superimposes the user's line of sight and the camera's optical axis.

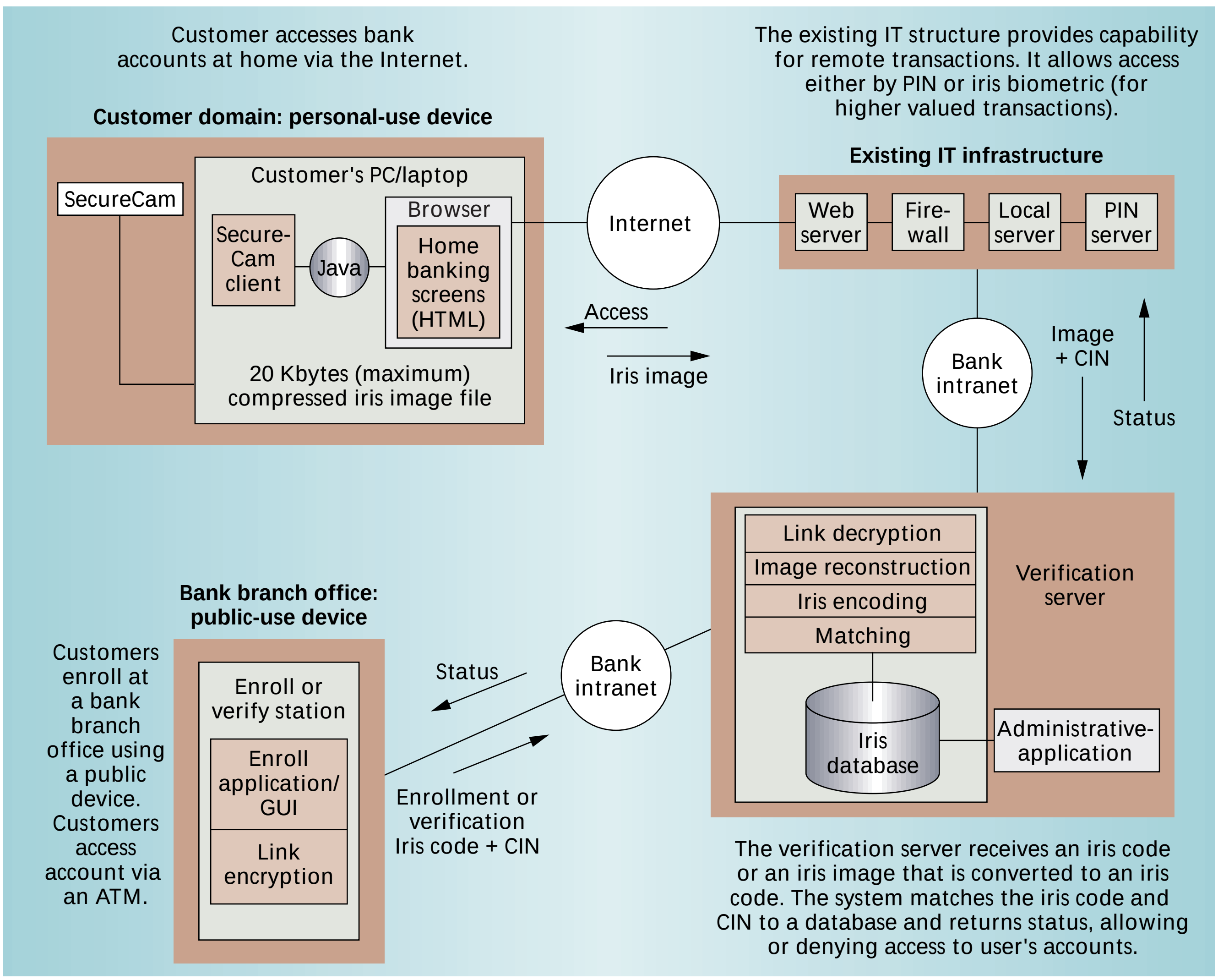


Figure 5. Diagram of the multichannel system architecture used to link public- and personal-use iris identification devices via corporate intranets and the Internet. The system uses each customer's PIN (personal identification number), iris code, and CIN (customer identification number) to validate transactions.

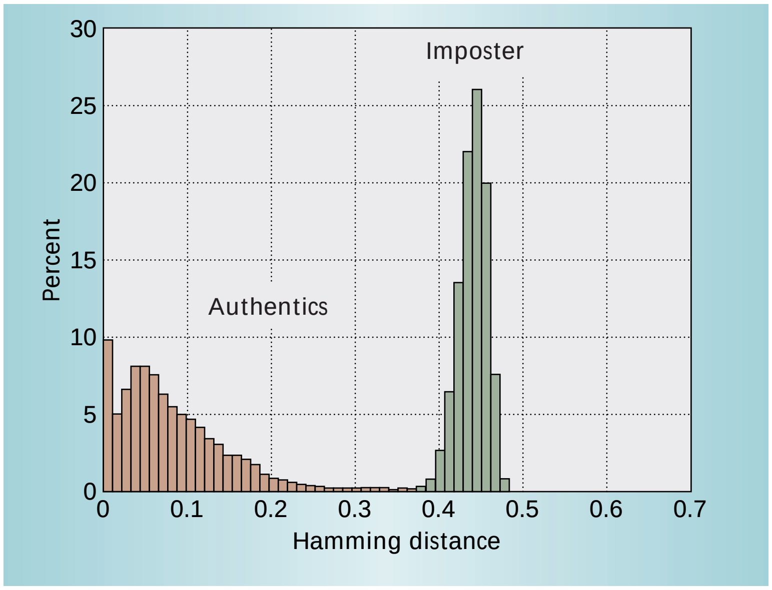


Figure 6. Verification distributions of authentics results (in brown) and imposter results (in green).

Statistical analysis of iris code comparisons shows the iris to be a discriminating biometric, with a lower limit error rate for false rejects and false accepts, equally, of approximately one in 1.2 million.[7] This extremely low error rate makes the iris ideal for large-database identification applications.

Figure 6 shows the authentics and impostor distributions derived from data collected under well-controlled experiments that emulate a consumer identification transaction. These distributions differ from other reported results[2] due to differences in the imaging platform and operational scenario. The separation between the distributions supports performance measures reported on other platforms.[2]

With an acceptance HD threshold set to 0.32, we have never experienced a false accept. In practice, our false-reject rate for a single try is approximately 0.5 percent for all users, with and without eyeglasses. In the rare case where we experience a false reject, a second try generally succeeds. Images that contain closed eyes due to eye blinks, misaligned eyes due to individuals looking the wrong direction, and eyes with momentary severe reflections due to eyeglasses or other imaging artifacts all contribute to false rejects. With good-quality iris images, the false-reject rate approaches zero.

Field trial experience

Our field trial experience has been very positive. The first pilot program—with the Nationwide Building Society in Swindon, England—ran for six months and included more than 1,000 participants, before going into regular service during the fourth quarter of 1998. The system is still used in everyday operations. Survey results of the participants showed that

- 91 percent prefer iris identification to a PIN (personal identification number) or signature,
- 94 percent would recommend iris identification to friends and family, and
- 94 percent were comfortable or very comfortable using the system.

The survey also found nearly 100 percent approval on three areas of crucial importance to consumers: reliability, security, and acceptability. In each case, iris identification outperformed the traditional methods of identification: PIN and signature. We currently have 12 pilot programs under way with different banking institutions in nine European, Asian, and North and South American countries, and expect to add pilot programs in Africa soon.

The systems we have described demonstrate that the iris can be used in both public and personal venues and, with the appropriate architecture, can provide remote and local positive identification, with interoperable devices at multiple sites. For many of these applications, the iris is the biometric of choice.

Complex vision systems are commonplace in sophisticated manufacturing and inspection environments. The public-use system we have described, however, represents possibly the most complex vision system yet used by consumers in a natural environment and without any special training required. We believe that this system foreshadows a more widespread deployment of such sophisticated technology to many different consumer environments. How the field of biometrics evolves in the marketplace remains to unfold, but the iris biometric will undoubtedly play a major role. ❖

Acknowledgments

IriScan Inc. of Marlton, New Jersey, holds the exclusive worldwide patents on the iris recognition software and process technology invented by John Daugman, Cambridge University, England. Sensar Inc. uses the iris recognition software and process technology in its products under license from IriScan Inc. Sensar Inc. also licenses Pyramid Vision and other technology from Sarnoff Corp. of Princeton, New Jersey. We thank Keith Hanna, Rick Wildes, Robbie Mandelbaum, Peter Burt, and other Sarnoff staff members for their technical excellence and invaluable hard work, which helped bring these technologies to the consumer market.

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