IREX V

Guidance for Iris Image Collection

NIST Interagency Report 8013

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Acknowledgements

Disclaimer

Contents

Errata

- July 2, 2014: Pixel and radius values in Figure 15 corrected.

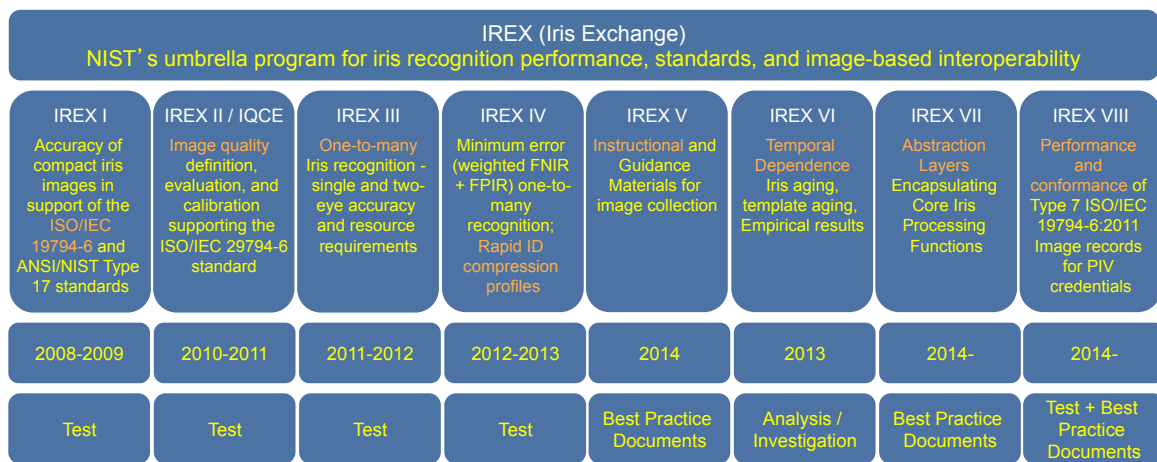| IREX (Iris Exchange) NIST's umbrella program for iris recognition performance, standards, and image-based interoperability							
IREX I Accuracy of compact iris images in support of the ISO/IEC 19794-6 and ANSI/NIST Type 17 standards	**IREX II / IQCE** Image quality definition, evaluation, and calibration supporting the ISO/IEC 29794-6 standard	**IREX III** One-to-many Iris recognition - single and two-eye accuracy and resource requirements	**IREX IV** Minimum error (weighted FNIR + FPIR) one-to-many recognition; Rapid ID compression profiles	**IREX V** Instructional and Guidance Materials for image collection	**IREX VI** Temporal Dependence Iris aging, template aging, Empirical results	**IREX VII** Abstraction Layers Encapsulating Core Iris Processing Functions	**IREX VIII** Performance and conformance of Type 7 ISO/IEC 19794-6:2011 Image records for PIV credentials
2008-2009	2010-2011	2011-2012	2012-2013	2014	2013	2014-	2014-
Test	Test	Test	Test	Best Practice Documents	Analysis / Investigation	Best Practice Documents	Test + Best Practice Documents

Figure 1: Timeline of the IREX program, including planned future installments.

1 The IREX Program

The IREX Program was initiated by NIST to support an expanded marketplace of iris-based applications. IREX provides quantitative support for iris recognition standardization, development, and deployment. To date, 6 activities have been completed and 2 more are tentatively planned (see Figure 1). Each is summarized below.

- **IREX I** [1] was a large-scale, independently administered, evaluation of one-to-many iris recognition. It was conducted in cooperation with the iris recognition industry to develop and test standard formats for storing iris images. Standard formats are important for maintaining interoperability and preventing vendor lock-in. The evaluation was conducted in support of the ISO/IEC 19794-6 [2] and ANSI/NIST-ITL 1-2011 [3] standards.

- **IREX II** [4] supported industry by establishing a standard set of quality metrics for iris samples. Although iris recognition has the potential to be extremely accurate, it is highly dependent on the quality of the samples. The evaluation tested the efficacy of 14 automated quality assessment algorithms in support of the ISO/IEC 29794-6 standard [5].

- **IREX III** [6] was a performance test of the latest iris recognition algorithms over operational data. Despite growing interest in iris-based technology, at the time there was a paucity of experimental data to support published theoretical considerations and accuracy claims. IREX III constituted the first public presentation of large-scale performance results computed over operational data.

- **IREX IV** [7, 8] builds upon IREX III as a performance test of one-to-many iris recognition. In addition to providing participants from previous evaluations an opportunity to further develop and test their recognition algorithms, this evaluation explored the potential for using a cost equation model for optimizing algorithms for specific applications. A second report identified optimal compression profiles for storing standard iris images compactly using JPEG 2000.

- **IREX V** provides guidance material (including this document) for the proper collection and handling of iris images.

- **IREX VI** [9] explored how the natural ageing of the iris impacts recognition accuracy. It investigated whether accuracy decreases as the time between enrollment and verification captures increases. Contrasting results between IREX VI and other published works [10] have emphasized the need for a revised definition of ageing.

- **IREX VII** intends to define a framework for communication and interaction between components in an iris recognition system. By introducing layers of abstraction that isolate underlying vendor-specific implementation details, a system can become more flexible, extensible, and modifiable.

- **IREX VIII** will test the performance of ISO/IEC 19794-6:2011 Type 7 images and lay the groundwork for conformance testing of Type 7 record generators.

The latest information on the IREX Program can be found on the IREX website (http://iris.nist.gov/irex).

2   Introduction

This document provides guidance for the proper collection of iris images. Poor quality iris samples are usually the result of problems that occurred during image collection. If the subject was looking down or blinking at the moment of capture, the image should be rejected and a new one acquired. Such problems tend to be fairly simple and straightforward to correct but require attentiveness on the part of the camera operator. If an image of a closed eye is accepted without scrutiny, no amount of post-capture image processing can recover the lost information. For this reason, certain procedures should be followed to ensure only good quality samples are collected.

The accuracy of automated iris recognition is highly dependent on the quality of the samples being compared [4, 11, 12, 13, 5, 14]. Evaluations of the technology have found that identification errors are predominantly caused by the poorest quality samples in the iris database. The IREX III: Failure Analysis Report [11] concluded that nearly every identification error that occurred for the most accurate matching algorithms in IREX III was caused by a severe quality-related problem (e.g. a closed eye). Most of the matching errors could have been prevented had certain corrective procedures been followed at the time of capture.

Iris cameras typically have built-in software that performs automated quality assessment. Most iris cameras will reject a sample if the software cannot find an iris in the image or if the iris is out of focus. Unfortunately, the quality filter in the camera itself is often coarse, and even when the camera is connected to a system capable of performing more thorough quality assessment, some sources of poor quality are extremely difficult for automated software to detect. For example, specular reflections (i.e. reflections off the surface of the eye) are often present in images collected outdoors and are very challenging for software to distinguish from true iris features. Thus, responsibility falls to the camera operator to not only detect these problems, but also perform the appropriate remedial action described in this document.

The problem of automated quality assessment of iris images was the focus of IREX II [4]. The evaluation measured the efficacy of several commercial and prototype quality assessment algorithms. It also supported the ISO/IEC 29794-6 [5] by advancing formal standards for iris sample quality, including a vector of quantitative metrics for assessing the utility of iris samples.

2.1   Audience

This document is for the benefit of iris camera operators. The recommendations provided are simple and straightforward because 1) collecting iris images can, admittedly, be a tedious task, and 2) it is often not the camera operator's primary responsibility in the field. Although the number of ways image collection can go wrong might appear quite numerous, a single adjustment can often rectify several problems at once. Thus, the operator only needs to remember a few simple procedures to deal with the majority of problems that might occur.

2.2   Terminology

The following terms are used in this document.

- **Iris Camera:** The camera used to acquire iris images. It is assumed to be hand-held but can be either a dual-eye (i.e. captures images of both eyes simultaneously) or single-eye (i.e. captures the eyes one at a time) camera.

- **Camera Operator:** The person operating the iris camera and the intended audience for this document. He or she does not need to have expert knowledge of iris recognition.

- **Subject:** The person whose iris images are being acquired. We assume that the subject is cooperative and that some amount of interaction is possible. The recommendations in this document do not require complex information to be conveyed to the subject that would require comprehension of a common language.

3   Common Acquisition Problems

This section describes the most common acquisition mistakes that lead to poor quality iris samples. Recommendations on how to manually identify and remedy each are provided. For ease of presentation, the problems are separated into three categories: 1) those caused by the camera operator, 2) those caused by the subject, and 3) those caused by the iris camera, either due to its software or hardware.

Although dealing with these problems at the time of capture requires additional effort on the part of the camera operator, doing so can actually lead to faster acquisition times by reducing the frequency at which the camera's built-in quality filter rejects images. Sometimes the remedial action is obvious (e.g. just acquire a new image), and the primary intent of describing the problem is to make the camera operator aware that it can occur.

3.1   Camera Operator

The following problems typically occur due to the behavior of the camera operator.

3.1.1   Occlusion by Finger

This occurs for some camera models when the operator accidentally places his or her finger over part of the camera lens. It is more likely to occur with compact single-eye cameras.
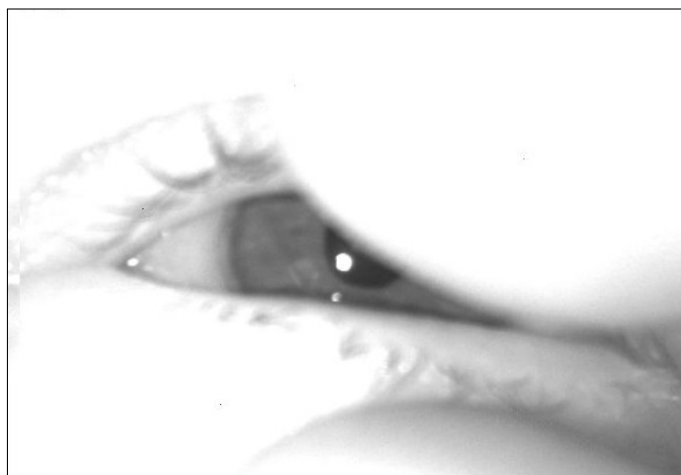
Figure 2: Example of occlusion caused by either the subject or the camera operator placing his or her finger in front of the iris.

EFFECT

Occlusion of part of the scene by the camera operator's fingers can obscure part of the iris, disrupt cameras with auto-focus lenses, and interfere with the iris camera illumination system or array, similar to blocking the flash of a conventional photo camera.

MITIGATION

A new image should be acquired if any part of the camera operator's fingers are visible. The camera operator should be careful not to place his or her finger(s) over the lens or in front of the camera's illumination array.

3.1.2   Motion Blur

Motion blur occurs when the camera is moving, or when the subject's head or eyes are moving, at the time of capture. Blur is most conspicuous around the normally sharply defined eyelashes. Motion blur is distinct from focus blur, which occurs when the iris lies outside the effective focal range of the camera. Motion blur is directional and can be recognized by stretching/streaking of specular highlights in the pupil along the line of motion.

Many commercial quality assessment algorithms can detect motion blur, and some even provide feedback revealing

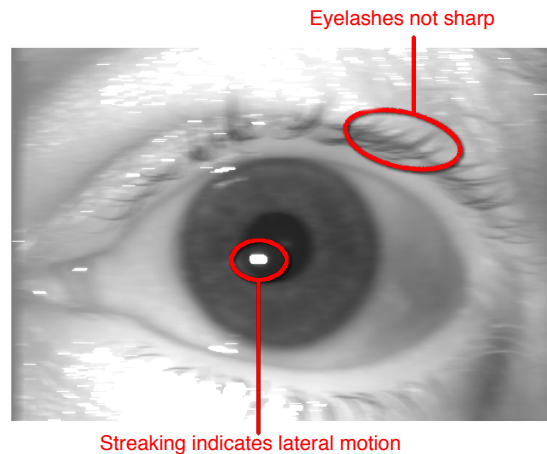motion blur as the source of the problem.

Figure 3: An example of an image with motion blur. The blur is easiest to notice around the normally sharply defined eyelashes. The shape of the specular highlight inside the pupil indicates motion in the lateral direction.

EFFECT

Acceptance of the image may lead to identification failures due to a loss of iris detail. Motional blur may cause the iris camera's internal quality filter to reject the image.

MITIGATION

Reacquire a new sample if the subject spontaneously moved at the moment of capture or if motion blur is obvious around the eyelashes. During reacquisition, hold the camera still and instruct the subject to remain motionless.

3.1.3 Mislabeled Eyes

This occurs when the labels for the left and right eyes are flipped (i.e. the left eye is labelled as the right and vice versa). It might arise due to confusion with respect to whether the right eye refers to the subject's right eye (correct) or the eye on the right from the perspective of the camera operator. The problem should only occur for single-eye cameras since dual-eye cameras should be able to automatically assign the correct labels.
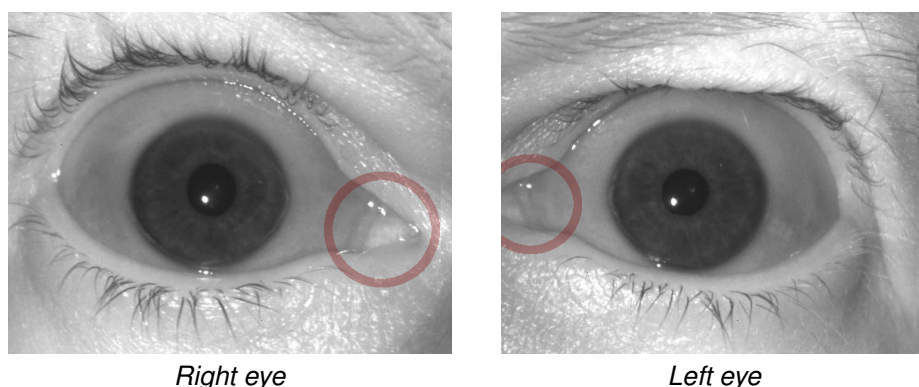

Right eye   *Left eye*

Figure 4: The proper labelling of the left and right eyes. 'Right' refers to the subject's right eye. The red circles highlight the nasal canthi, which lie on the nasal side of the eye. The nasal canthus should be on the right in the image of the right eye.

EFFECT

Mislabelling can lead to failed attempts at identification if the iris recognition system only compares images having the same left or right eye label.

Standards require the eye's orientation (left or right) to be encoded. If the labels are incorrect, they should be corrected, or the iris images should be reacquired in the correct order if the camera requires the left and right eyes to be acquired in a specific order.

3.1.4 Eye Rotation

An image may contain a rotated eye either because the subject's head was tilted at the time of capture or because the camera was being held at an angle. The line connecting the canthi (corners of the eye) should be approximately horizontal. High rotation amounts are more likely to occur for single-eye cameras since dual-eye cameras typically require the subject's head to be approximately aligned with the camera (and even when rotation is present, it can be estimated from the locations of the irides in both images).
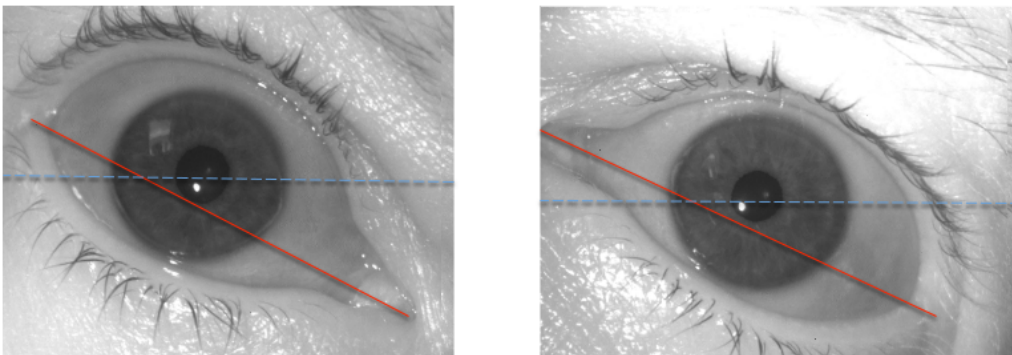

Figure 5: Examples of highly rotated eyes. The red line segments connecting the corners of the eyes should be approximately horizontal.

EFFECT

Highly rotated eyes can lead to identification failures. Most iris matchers compare iris samples over a restricted range of rotation disparities. Minimizing rotation can improve recognition accuracy as well as reduce comparison time if the amount of rotation is known to be small.

MITIGATION

Although it is difficult to visually quantify the amount of rotation in an iris image, rotations of more than about 15 degrees should lead to rejection. Only some single-eye cameras can detect rotation at the time of capture, so the camera operator should remain vigilant to the problem of eye rotation. The iris camera should be held fully upright without any tilt. If the subject is supine or in an otherwise atypical position, the camera should still be properly aligned with the subject's head.

3.2 Subject Behaviour

This section addresses problems attributable to the subject's behaviour or state.

3.2.1 Closed or Squinting Eye

Eyelid occlusion occurs when the eyelids obscure part of the iris. Some amount of occlusion is expected (especially by the upper eyelid) and should not be grounds for rejecting a sample as long as it is not severe. Severe amounts of occlusion are sometimes caused by the subject blinking or looking down at the moment of capture. Sometimes medical conditions are the cause. A subject will have greater difficulty opening his or her eyes if he or she is facing a bright source of light, such as the sun.

Most commercial iris quality assessment software can detect high amounts of occlusion and prompt the camera operator to recapture. The camera operator should nevertheless remain aware of the problem, especially since adjustments to how the iris is captured can reduce the frequency at which samples must be reacquired.
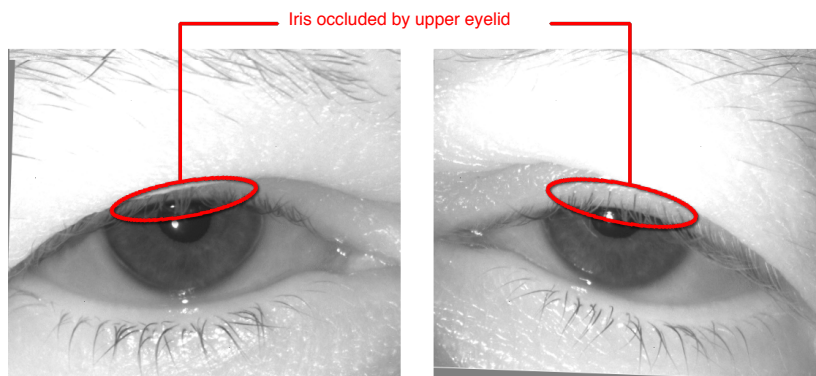
Figure 6: Examples of iris images with severe amounts of eyelid occlusion. Note that the upper eyelids trespass on the pupil region.

EFFECT

A severely occluded iris can be difficult for the camera software (or iris matcher) to localize. Even if properly localized, the limited amount of visible iris texture will make recognition more difficult. Many iris cameras will not accept an iris image if they detect severe amounts of occlusion.

MITIGATION

A new image should be acquired if the existing one contains severe amounts of occlusion. A good rule-of-thumb is to accept the image only if the upper-eyelid does not trespass into the pupil area. If the iris camera refuses to accept an image due to high amounts of occlusion, the subject can be instructed to open his or her eyes wider, using his or her fingers as necessary.

The subject should not be facing a bright source of light, which can cause squinting. In addition, any bright sources of ambient light within the subject's field of view can introduce specular reflections (see section 3.3.4).

3.2.2 Specular Highlights from Glasses

Eyeglasses and other types of eye wear can introduce specular highlights (bright spots of light) and glare. Specular highlights have a tendency to appear over the iris since the subject is required to face the camera. Scratches on the lenses superimposed on the iris can also introduce problems for automated matching algorithms.
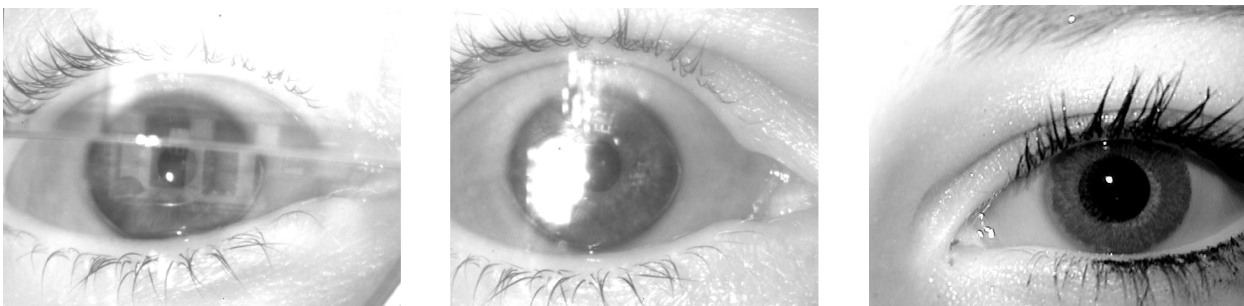

Figure 7: Examples of glare and specular highlights caused by glasses (left two irides) and an iris obscured by a patterned contact lens (right). Features may not present well in paper printouts.

EFFECT

Specular highlights occlude the iris and make localizing the iris boundaries more difficult. Glare can also introduce false iris features that are extremely difficult for recognition algorithms to distinguish from true iris features. Vision correction lenses may also distort the appearance of the iris.

Non-patterned contact lenses have a small but measurable impact on recognition accuracy [10]. Patterned contact lenses are not common but will make recognition extremely difficult if not impossible.

Eyeglasses and other types of easily removable eye wear should be removed before acquisition. Most iris cameras cannot detect eye-wear at the time of capture, so it is the responsibility of the camera operator to notice when subjects are wearing eye-wear and ask subjects to remove them.

Non-patterned contact lenses do not have to be removed. Patterned contact lenses (see Figure 7) can be difficult to detect, but should be removed if possible. There is little matching utility to acquiring a sample of an iris that is mostly obscured by a patterned contact lens.

3.2.3   Off-axis Gaze

Off-axis means the subject was not looking at the camera at the time of capture. The subject may have been looking up, down, left, right, or a combination of these. The subject should also be facing the camera. Most commercial quality assessment algorithms attempt to detect off-axis gazes.
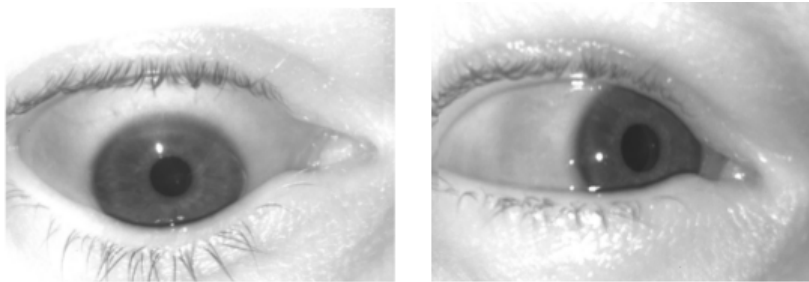

Figure 8: Examples of eyes with off-axis gazes. The subject should be looking directly at the camera.

EFFECT

An off-axis gaze introduces perspective distortions to the iris and can increase occlusion by the eyelids. It also makes the iris boundaries appear less circular (and more elliptical), which introduces difficulties for algorithms that attempt to localize the iris under the assumption that has a near annular shape.

MITIGATION

A new image should be acquired. Most single-eye cameras cannot detect off-axis gazes at the moment of capture, so it is the responsibility of the camera operator to notice the problem. The subject should be instructed to face straight ahead and look at the iris camera.

3.2.4   Highly Dilated or Constricted Pupil

Several factors affect the size of the pupil. Although ambient lighting is the dominant factor in most cases, certain drugs and even a person's psychological state can affect pupil size.
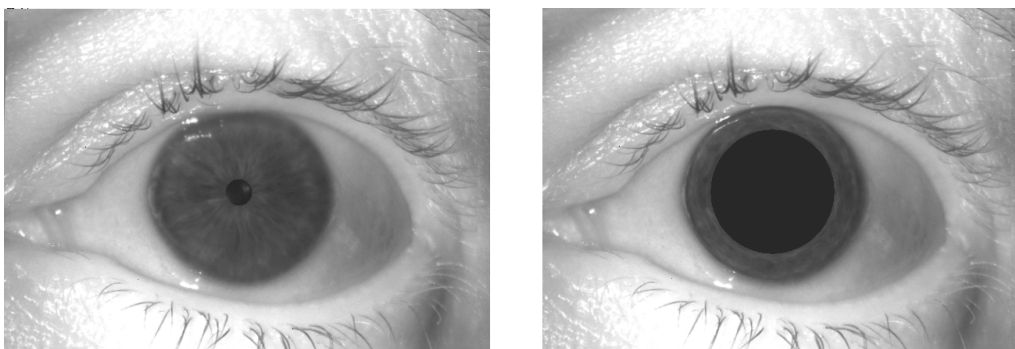

Figure 9: Examples of images with highly constricted (left) and highly dilated (right, simulated) pupils.

The effect of dilation change on recognition accuracy is well documented [4, 6, 9, 15, 16] in the literature. Variations in pupil size cause complex non-linear deformations to the iris that degrade recognition accuracy.

Excessive and abnormal amounts of pupil dilation or constriction should be avoided. Ideally, ambient lighting at the capture location is diffuse and reflects typical daytime conditions (i.e. it is not overly bright or dark). In some cases it may be possible to move to another location where lighting is more conducive to acquisition. The subject should not be facing a bright source of light, such as the sun.

Handling situations where the subject's pupils are abnormally dilated or constricted due to drugs or intoxication is scenario dependent. When possible, wait until the drug (or intoxication) wears off.

3.3 Iris Camera

This section addresses acquisition problems most strongly associated with the iris camera itself. Hardware malfunctions are serious because they affect all images acquired by the camera until the problem is fixed.

3.3.1 Focus Blur

Focus blur usually occurs because the subject is standing too close or too far from the iris camera. It is most noticeable around the normally sharply defined eyelashes. Focus blur is distinct from motion blur, which is caused by movement of either the iris camera or the subject at the moment of capture.
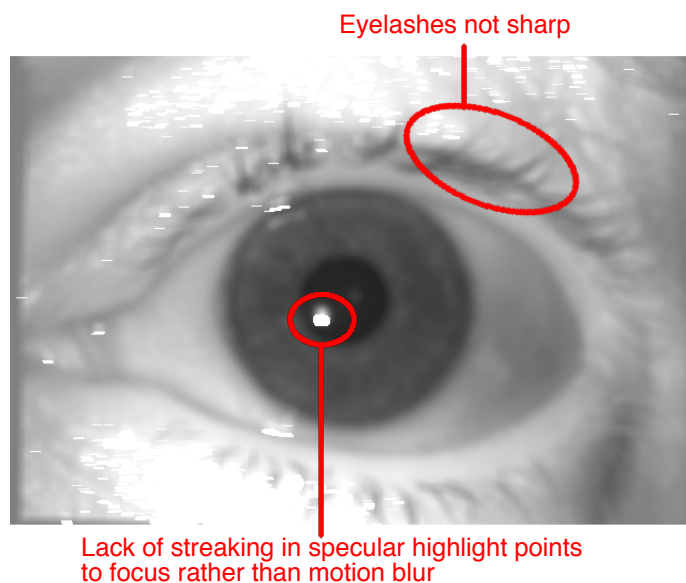

Figure 10: An example of an out-of-focus image (simulated). Note the lack of directional blur or streaking of the specular highlight inside the pupil which differentiates it from motion blur.

Focus blur reduces recognition accuracy due to the loss of iris texture detail. Severe amounts of focus blur may cause the iris camera to reject the image.

Reacquire the image with the subject's eye at the proper distance from the camera if blur is obvious. Focus blur is most noticeable around the eyelashes. Ensure the camera lens is not smudged. If the blur is caused by mis-calibration of the camera or some other type of malfunction, the camera will have to be fixed or replaced.

3.3.2   Iris Absent from Image

This occurs when the person's iris is not in the image, typically because the camera software mis-identified some other part of the face as the iris. This is known to sometimes occur around eyeglass frames.
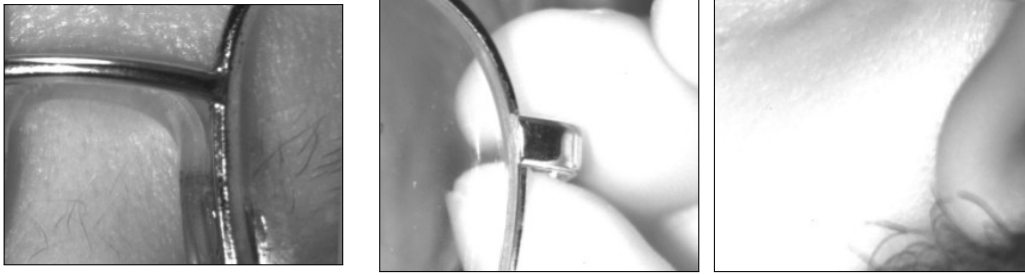

Figure 11: Examples of images where the camera failed to properly locate the iris.

EFFECT

Attempts at identification will fail because the iris is completely absent from the image.

MITIGATION

Reacquire a new image containing the iris. Ensure eyeglasses are removed.

3.3.3   Uneven Illumination

Sometimes the eye is illuminated in a non-uniform manner such that one side of the eye is noticeably brighter than the other. The typical cause is one or more burnt out LEDs on the iris camera.
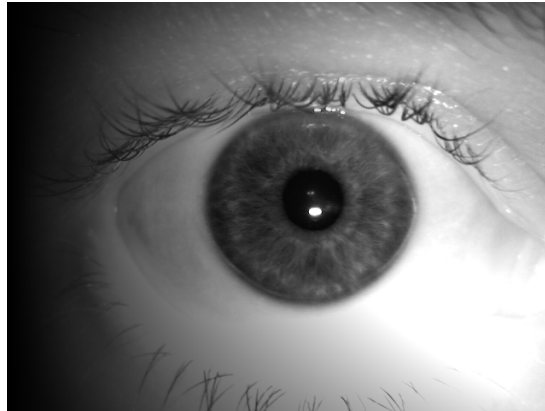

Figure 12: An example of an iris that is not uniformly illuminated.

EFFECT

Recognition accuracy will drop because some iris features will be less visible than others. Highly directional light will also alter the appearance of the iris features since the iris is not a flat surface (consider the way a topological view of terrain changes depending on the time of day). Uneven illumination may also cause the iris camera's internal quality filter to reject the image.

MITIGATION

If the non-uniform illumination is caused by burnt out LEDs on the camera, they should be replaced. If the problem is caused by ambient illumination, the camera operator should move to a location where ambient illumination is more equable.

3.3.4   Specular Reflections

Specular reflections (also known as Purkinje images) are reflections of a scene off the surface of the eye. They typically show what is in front of or behind the subject. Some cameras have shields that block peripheral light from reflecting off of the iris and creating these reflections. Others have special imaging and illumination technology that mitigate such reflections.
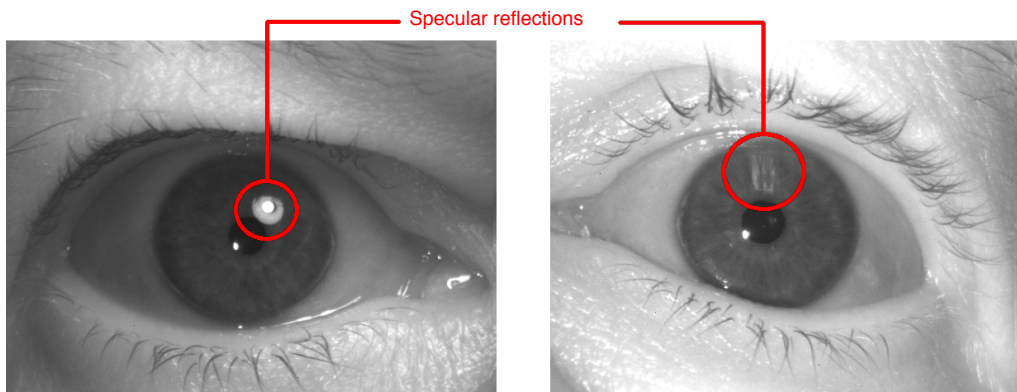

Specular reflections

Figure 13: Examples of specular reflections (i.e. Purkinje images) on the surface of the eye.

EFFECT

Specular reflections create false features on the iris that negatively impact recognition accuracy. These features are extremely difficult, if not impossible, for recognition algorithms to distinguish from true iris features. For this reason, it is the responsibility of the camera operator to notice the problem and take appropriate remedial action.

MITIGATION

A new image should be acquired, but preventing specular reflections from appearing in new acquisitions can be difficult. If possible, reposition the subject such that the scene before him is not busy and thus does not have much to reflect. That said, the camera operator will always be standing in front of the subject.

Another solution is to change the position of the subject relative to the main sources of ambient light. If capturing outdoors, positioning the subject perpendicular to the sun (i.e. with the sun off to the left or right) is likely to reduce specular reflections. Do not have the subject face the sun, which is likely to increase specular reflections as well as eyelid occlusion due to squinting (see section 3.2.1).

3.3.5 Low Contrast

This occurs when the image as a whole appears dark without much contrast. There are several possible causes: 1) one or more LEDs on the camera are burnt out, 2) the camera operator's fingers are obscuring part of the camera lens, or 3) the camera software is mis-calibrated or otherwise malfunctioning.
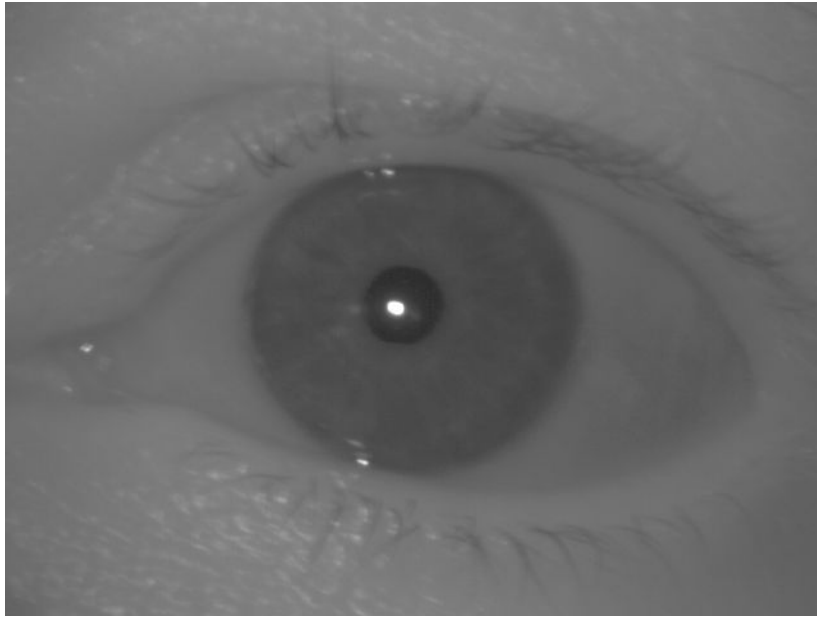
Figure 14: An example of an iris image with low contrast.

EFFECT

Low contrast reduces recognition accuracy because the iris features are less pronounced and detail is lost. Low contrast also makes localization of the iris boundaries more difficult.

MITIGATION

When applicable, ensure the operator's finger is not occluding any part of the camera lens. If possible, check that the camera is not mis-calibrated and that all LEDs are fully functioning.

4 Summary of Recommendations

The following is a brief summary of the recommendations presented earlier on how to avoid the collection of poor quality iris samples. These recommendations are not comprehensive. The previous sections should still be referenced as necessary, particularly with respect to how to setup the capture environment to avoid capturing poor quality samples in the first place.

▷ **Capture Environment:** Ideally, ambient lighting is diffuse and reflective of typical daytime conditions. If the iris camera does not block ambient sources of illumination, neither the subject nor the camera operator should be facing bright sources of light, such as the sun. Ensure all LEDs are emitting light.

▷ **Prior to Capture:** Ensure the subject has his eyeglasses removed. Instruct the subject to remain still and to face, and look at, the camera. The subject may use his fingers to open his eyes wider if necessary.

▷ **During Capture:** Ensure the camera is held still, is properly aligned with the subject's face, and that the operator's fingers are not obscuring any part of the camera lens or illumination array.

▷ **Post-Capture:** Ensure the iris is present and centered in the image, is not blurry, and is well illuminated. Ensure the upper-eyelid does not cross into the pupil and that the iris is not severely rotated (i.e. is greater than approximately 15 degrees).

Ideally, the iris camera will be connected to a system that performs a more thorough and powerful assessment of sample quality than the camera's own built-in quality filter, and makes a final accept/reject decision.
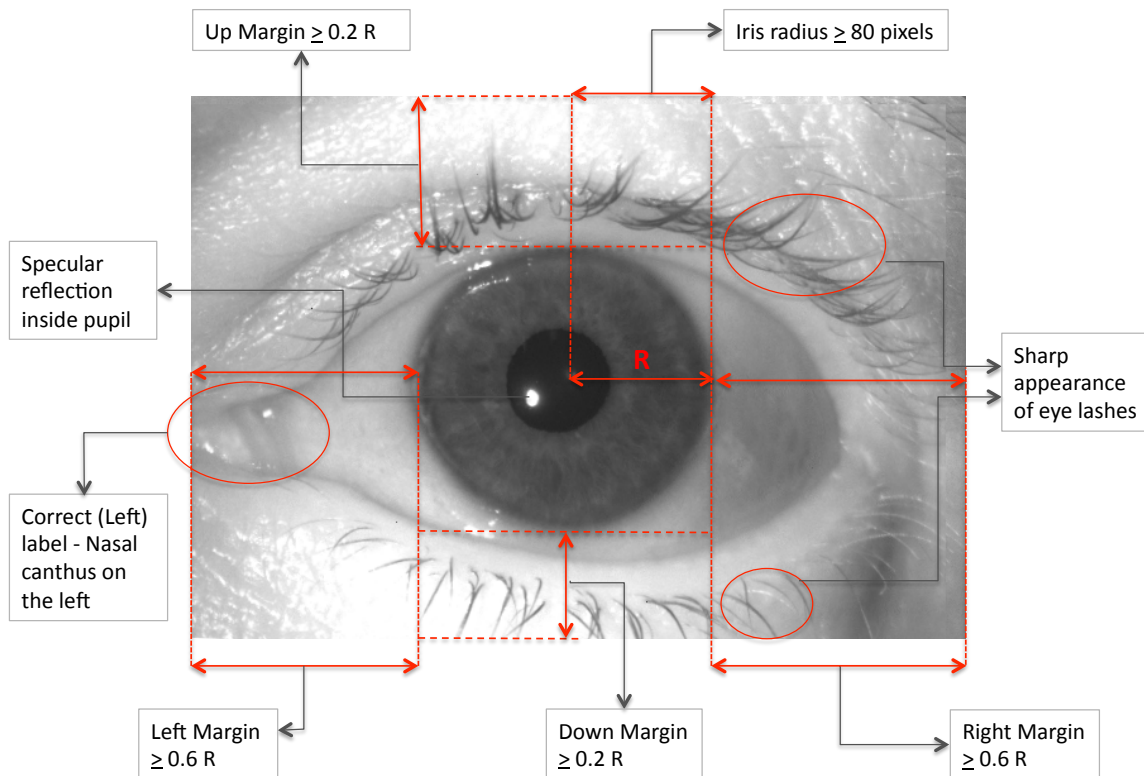
Figure 15 shows an example of a good quality iris image.

Figure 15: An example of a good quality iris image, with some of its desirable properties marked up.

5 References

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[2] *ISO/IEC 19794-6 - Biometric Data Interchange Formats - Iris Image Data.* 2011. 1

[3] *ANSI/NIST-ITL 1-2011 Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information.* 2011. 1

[4] E. Tabassi, P. Grother, and W. Salamon, "IREX - IQCE Performance of Iris Image Quality Assessment Algorithms." http://www.nist.gov/itl/iad/ig/irexii.cfm, 2011. 1, 2, 8

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[7] G. W. Quinn, P. Grother, and M. Ngan, "IREX IV Part 1: Evaluation of Iris Identification Algorithms." http://www.nist.gov/itl/iad/ig/irexiv.cfm, 2013. 1

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