



IREX IV

Evaluation of One-to-Many Iris Recognition
Concept, Evaluation Plan, and API Specification
Version 1.0

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1 Status of this Document

- 2 This is the third public version of this document. Comments and questions should be submitted to irex@nist.gov.
 3 This document can be downloaded from <http://iris.nist.gov/irex>.

4 Timeline

Table 1: Milestones and deadlines

Sept 16, 2012	Tentative target deadline for first public report.
June 28, 2012	Last day to submit and still receive an interim report back.
May 16 - August 2, 2012	Submission window.
May 16 - August 2, 2012	If you have not already done so, organizations are kindly asked whether they will participate. Please send a non-binding best guess email to irex@nist.gov .
May 16, 2012	Final API released.
May 14, 2012	Comments due on version 0.2 of API
May 4, 2012	NIST releases API version 0.2
May 1, 2012	Comments due on Initial API
April 16, 2012	NIST releases API version 0.1

5 Release Notes

- 6 *Changes relating to the third release of this document are highlighted with a pink background color. The only changes are to the timeline above.*

Changes relating to the second release of this document are highlighted with a green background color. Most notably:

1. *The submission window has been extended to Aug 2, 2012.*
2. *The process of interim reporting of results is explained in greater detail in Section 2.4.2.*
3. *The dead links pointing to the encryption procedures and participation agreement have been corrected.*
4. *The **decision** parameter of **identify_template()** is now a pointer type.*
5. *gcc version 4.4.6 is now specified as the system that will be used to link the libraries.*

- 8 *NOTE: IREX IV is very similar to IREX III with respect to its API and implementation requirements. Notable changes are highlighted throughout this document with a yellow background color.*

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48 Terms and Definitions

Table 2: The following terms and definitions are used in this document

ANSI	American National Standards Institute
ANSI/NIST Type 17	American National Standard for Information Systems - Data Format for the Interchange of Fingerprint, Facial, and Other Biometric Information - Part 1
API	Application Programming Interface
EDB	Enrollment Database
FNIR	False Negative Identification Rate
FPIR	False Positive Identification Rate
FTS	Failure to search
FTX	Failure to extract features from an enrollment image
DET	Detection Error Tradeoff
ISO	International Standards Organization
ISO/IEC 19794-6	ISO/IEC standard titled "Information technology - Biometric data interchange formats - Part 6: Iris image data"
ISO/IEC 29794-6	ISO/IEC standard titled "Biometric Sample Quality - Part 1: Framework"
IREX	Iris Exchange
NIST	National Institution of Standards and Technology
UID	India's Unique Identity scheme

49 1 IREX IV Concepts

50 1.1 Overview

51 This document establishes a concept of operations (CONOPS) and application programming interface (API) for the
52 Iris Exchange (IREX) IV Evaluation. IREX IV will be a large-scale evaluation of iris recognition technology over
53 operational data. Like IREX III [1], it will focus exclusively on one-to-many applications.

54 The goals of this evaluation are

- 55 • To investigate the use of cost parameters for application specific optimization (see Section 2.1.2).
- 56 • To establish a compression profile for the efficient and compact storage of iris images (see Section 2.1.3).
- 57 • To measure the speed and accuracy of iris matchers over the OPS-II dataset of operational iris images.

58 This marks the fourth installment in the IREX program (see Figure 1). See <http://iris.nist.gov/irex> for all IREX related
59 documentation.

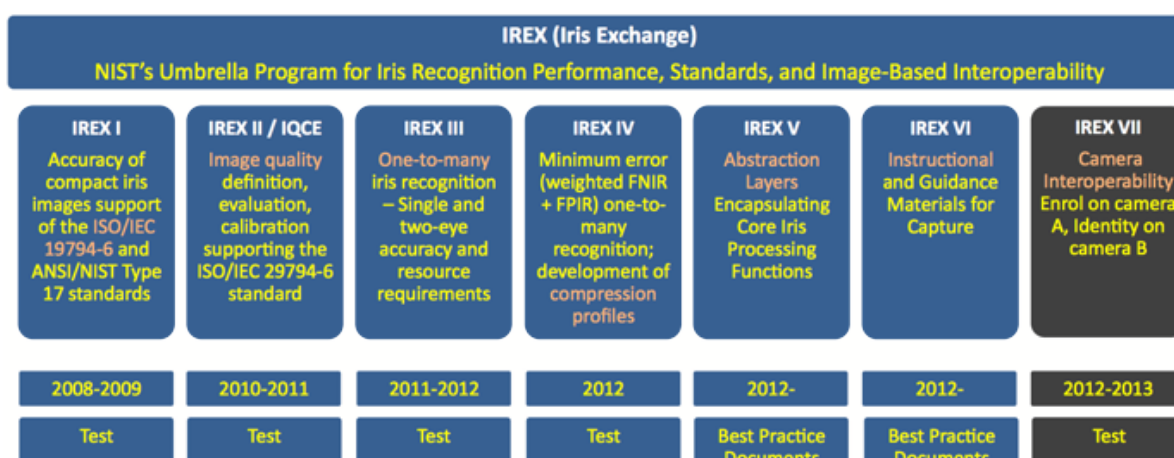
60 1.2 Market Drivers

61 This evaluation is intended to support a plural marketplace of iris recognition systems. While the largest applica-
62 tions, in terms of revenue, have been for border control and war zone identity management, India's Unique Identity
63 (UID) scheme is currently using iris (in conjunction with fingerprints) for de-duplication on a massive scale.

64 The expanding marketplace for iris recognition has fueled the development of iris cameras designed to operate in
65 a variety of applications. For example:

- 66 • Some standoff-capture cameras can rapidly image and verify (in a one-to-many mode) high volumes of
67 people.

Figure 1: Current extent of the IREX program as well as planned expansions.



68 • Some mobile cameras can be preloaded with firm-ware based segmentation and identification capability for
69 rapid one-to-many watchlist searches.

70 These applications are differentiated by population size, hardware capabilities, quality of the iris samples, and other
71 variables.

72 1.3 Application Scenarios

73 The evaluation will focus on practical applications of iris recognition with an emphasis on large-scale deployments
74 (i.e. where the enrollment database contains up to several million subjects). The interest is in *one-to-many open-set*
75 identification systems. Systems operating in a *one-to-many* mode (sometimes referred to as "identification mode")
76 are tasked with identifying the individual without a prior claim to identity. *Open-set* means there is no guarantee
77 that the searched individual is enrolled in the database. To explore the potential for application-specific algorithm
78 optimization, participants will submit two classes of implementations, each focusing greater attention on reducing
79 a different type of error (see section 2.1.2). Table 3 details the parameters of this evaluation.

80 Participants may also submit implementations that perform cropping and masking of the iris images to convert
81 them into an ISO/IEC 19794-6 compact format. Representing iris images compactly is crucial for applications
82 operating over limited-bandwidth networks. India's Unique Identity (UID) scheme is seeking to reduce bandwidth
83 requirements for the transmission of iris data.

84 2 Evaluation Overview

85 The evaluation will be conducted offline. Offline evaluations are attractive because they allow uniform, fair, re-
86 peatable, and convenient testing. However, they do not capture all aspects of an operational system. While this
87 evaluation is designed to mimic operational reality as much as possible, it does not include a live image acquisition
88 component or any interaction with real users.

Table 3: Application Parameters

Parameter	Class P (Positive Identification System)	Class N (Negative Identification System)
Application Type	One-to-many open-set identification systems (e.g. watchlists, de-duplication operations).	
Class Description	High cost associated with false positives	High cost associated with false negatives
Example Applications	Biometric authentication for restricted access to high value information, resources, or facilities.	Watchlists for high-profile individuals. Investigational-mode searches.
Enrolled Database Size	Anywhere from $O(10^2)$ to $O(10^7)$ subjects.	
Prior NIST References	IREX III Final Report [1] IREX III Supplement I: Failure Analysis [2] Multiple Biometric Evaluation (MBE) 2010 [3]	
Performance Criteria	Primarily accuracy and speed. Also, memory usage, scalability, template-size, etc.	

89 2.1 Performance Metrics

90 2.1.1 Accuracy

91 Accuracy will be measured for open-set applications, which means that no assumption can be made as to whether
92 the searched individual is enrolled in the database. Most real-world applications of biometrics operate in this way
93 (e.g. watchlists and de-duplication tasks). Closed-set applications, which assume that every searched individual
94 is enrolled in the database (and thus only concern themselves with *which* of those enrollees the searched person
95 matches best) are operationally uncommon and will not be tested.

96 Open-set biometrics systems are tasked with searching an individual against an enrollment database and returning
97 zero or more candidates. Two types of decision errors are usually considered for this type of system. The first
98 occurs when a candidate is returned for an individual that is not enrolled in the database. This is referred to as a
99 false positive. The second occurs when the correct candidate is not returned for an individual that is enrolled in the
100 database. This is referred to as a false negative.

101 NIST will compute false positive statistics exclusively from non-mated searches and false negative statistics exclu-
sively from mated searches. Although this reflects operational reality better than computing false positive statistics
from mated searches (by simply ignoring correct mates on the candidate lists), it does not cover all factors that
could affect the accuracy of a system (e.g. the position of the correct mate on the candidate list, the number of
incorrect candidates returned for a mated search).

102 This evaluation will present core matching accuracy in the form of Detection Error Tradeoff (DET) [4] and Sensitivity-
103 Reliability [5] plots, both of which show the tradeoff between the two types of error. The Application Programming
104 Interface (API) will require searches to return a fixed number of candidates but will only consider a candidate
105 viable if its dissimilarity score is below some decision threshold. Table 4 defines how the accuracy metrics will be
106 computed.

107 In some plots, line segments will be drawn between curves to connect points of equal threshold. These line
108 segments are intended to show how error rates at specific operating thresholds vary depending on factors such as
109 the number of entries in the enrollment database or the quality of the iris samples.

Table 4: DET and SEL-REL accuracy metrics

Performance Plot	Metric	Description
Detection-error Tradeoff Curve	FPIR	The fraction of non-mated searches for which at least one candidate has a distance score at or below threshold.
	FNIR	The fraction of mated searches for which the correct candidate is not on the list or has a distance score above threshold.
Selectivity-Reliability Curve	SEL	The average number of candidates for a non-mated search having a distance score at or below threshold.
	REL	One minus FNIR

110 2.1.2 Cost Function Optimization

111 This evaluation will investigate the use of cost parameters for application-specific algorithm optimization. The goal is to determine if matching algorithms can be modified to improve performance when the costs of errors are known in advance. The following cost model will be used as an evaluation metric for recognition performance:

$$112 \quad E[\text{Cost}(\tau)] = (1 - P_{Mated}) \text{FPIR}(\tau) C_P + P_{Mated} \text{FNIR}(\tau) C_N \quad (1)$$

113 where P_{Mated} is the *a priori* probability that the user of the system is mated, C_P is the cost of a false positive, C_N is the cost of a false negative, $\text{FPIR}(\tau)$ is the false positive identification rate, $\text{FNIR}(\tau)$ is the false negative identification rate, and τ is the operating threshold. The model estimates the expected cost per user attempt, which could be a measure of time, workload, money, etc. The participant is tasked with minimizing the cost for a predetermined and fixed set of cost parameters (C_P , C_N , and P_{Mated}).

114 Cost parameters are often chosen to correspond to a specific application. Consider a biometric system that provides bank vault access to specific individuals. One might reasonably set the cost of a false positive to be the monetary value of whatever is in the vault, and the cost of a false negative to a value that reflects the amount of inconvenience incurred from having to open the vault by some other method. Setting P_{Mated} to 0.1 assumes that one out of every ten access attempts is by an allowed user.

115 NIST requires each participant to submit two implementations, each corresponding to a different set of cost parameters. These parameters are defined in Table 5. Class P implementations penalize false positives heavily and false negatives lightly. Class N implementations assign comparatively greater penalty to false negatives. For this class of implementations, suppression of false positives is less important. Both classes will be tested over one-eye and dual-eye tests. Participants may wish to use a different fusion rule for the two class types.

Table 5: Cost parameters for both submission types

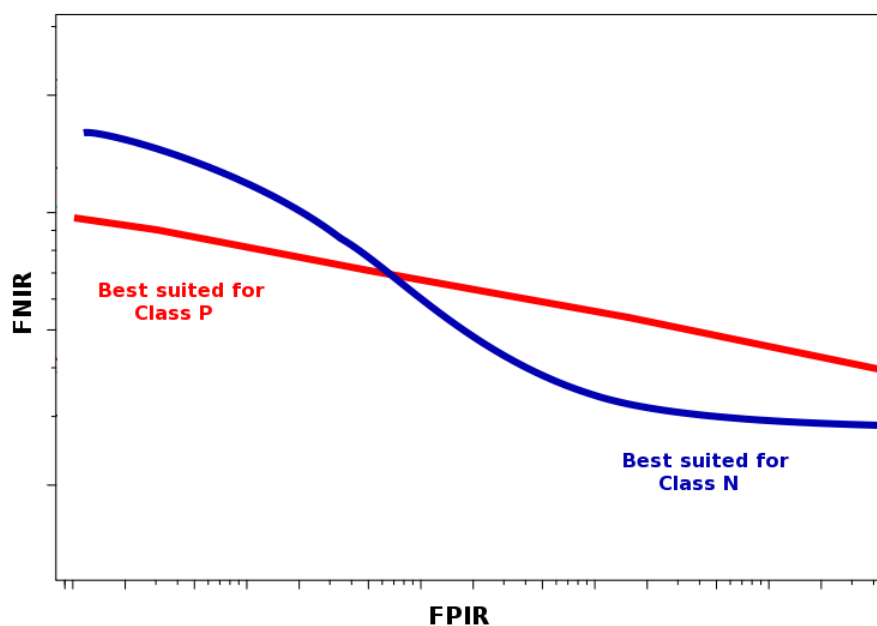
Implementation Class	C_N	C_P	P_{mated}
Class P	1	10	0.01
Class N	200	1	0.1

116 Additionally, failures to extract (FTXs) and failures to search (FTSs) will be treated differently depending on the implementation class. For Class P implementations, both will be treated as failures in a *positive recognition system* (e.g. access control). This is the way NIST has handled FTXs and FTSs in prior evaluations. For Class N implementations, FTXs and FTSs be treated like failures in a *negative recognition system* (e.g. a watchlist). Failures in a negative recognition system increase the FPIR when they occur for non-mated searches, but do not increase the FNIR when they occur for mated searches. This differs from the way NIST has traditionally handled these types of failure.

117

The motivation for requiring participants to submit two implementations is to see if it is possible to change the shape of a DET to reduce cost for a specific set of cost parameters. Figure 2 plots standard DET curves for two identification algorithms. The two curves cross one another, making it impossible to state which is more accurate in any absolute sense. Since Class N implementations are penalized heavily for false negatives, and only lightly for false positives, both algorithms are expected to achieve their lowest cost toward the right end of the figure, where the blue curve performs better. Conversely, Class P implementations are penalized heavily for false positives but only lightly for false negatives. Thus, for this set of cost parameters, both algorithms are expected to achieve their lowest cost toward the left end of the figure, where the red curve performs better.

Figure 2: Notional DET plots demonstrating how the two classes place greater emphasis on different regions of the DET.



118 2.1.3 JPEG 2000 Compression

119

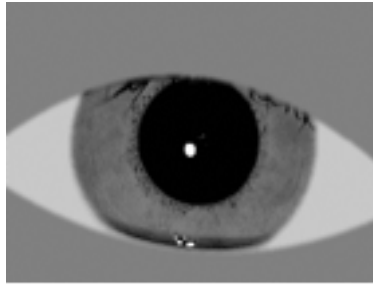
India's UID scheme will use the iris biometric for recognition tasks, and a desire has been expressed to represent iris feature information more compactly to reduce bandwidth usage during network transfer. The ideal solution is to store the images according to one of the compact and interoperable formats specified in ISO/IEC 19794-6. This evaluation seeks to further support the standard by establishing JPEG 2000 compression profiles for the efficient and compact storage of iris images. Toward this end, NIST will subject the images to lossy JPEG 2000 compression while tweaking various compression parameters. JPEG 2000 encoders that NIST may use include OpenJPEG [6] and Kakadu [7]. Participants are requested to submit implementations that can convert a raw iris image into an ISO/IEC 19794-6 Type 7 (cropped and masked) image (as shown in Figure 3). Support for this operation is optional but encouraged.

120 2.1.4 Single-eye and Dual-eye Testing

121 NIST will evaluate performance for scenarios where:

- 122 • one iris sample is available per person.
- 123 • two samples (of opposite eyes) are available per person.

Figure 3: An example of an ISO/IEC 19794-6 Type 7 (cropped and masked) image.



124 Due to the high frequency of erroneous (left/right) eye labelings in the OPS-II dataset, NIST will no longer provide labeling information for iris samples. All samples will simply be labeled "U", indicating "Unknown". NIST suspects the mislabelings are due to ambiguity with respect to whether "left" is intended to represent the subject's left eye (correct) or the eye on the left from the perspective of the camera operator (incorrect).

125 NIST will never provide more than two samples per person. Although eye labels will not be provided, it can be assumed that if two samples are provided, they represent opposite eyes of the same person.

126 When testing single-eye performance, NIST will enroll left and right eyes of one person under different identifiers
127 as though they came from different persons. This will allow NIST to test over larger enrollment databases. The test
128 harness will never enroll two samples of the same iris under different identifiers.

129 2.1.5 Accuracy-speed Trade-off

130 NIST will perform an analysis of the trade-off between speed and accuracy. However, participants are no longer re-
131 quested to submit implementations of varying speeds. Rather, participants should submit different implementations
132 that are each optimized to a different set of cost function parameters (see Section 2.1.2).

133 2.1.6 Timing Statistics

134 NIST will report the computation time for all core functions of the implementations (e.g. feature extraction, search-
135 ing). As was done in previous IREX evaluations, search time will be plotted as a function of enrollment size with
136 a focus on whether the trend is sub-linear for any of the implementations. Batch mode processing, where more
137 than one search is conducted at a time, will not be tested. Timing estimates will be made on an unloaded machine
138 running a single process at a time. The machine's specifications are described in Section 2.3.0.1.

139 2.1.7 Template Sizes

140 The size of the proprietary templates generated by the implementations is relevant because it impacts storage
141 requirements and computational efficiency. Therefore, NIST will report statistics on the size of enrollment and
142 identification templates.

143 2.1.8 Runtime Memory Usage

144 NIST will monitor runtime memory usage during one-to-many searches and report the results.

145 2.1.9 Automated Quality Assessment

146 Automated quality assessment has a number of useful applications in iris recognition (e.g. determining in real-time
147 whether a sample should be reacquired during a capture session). Automated quality assessment of iris samples
148 was the primary focus of IREX II: IQCE [8]. In IREX IV, NIST will analyze the quality scores returned by the

149 implementations during feature extraction. Error vs. reject curves, as described in [9], will be plotted. NIST may
150 choose to perform additional analyses with an emphasis on how strongly quality scores correlate with matching
151 accuracy. Support for automated quality assessment in the submitted implementations is optional.

152 2.2 Iris Datasets

153 2.2.1 The OPS-II Dataset

154 The primary test dataset for this evaluation is identical to the OPS dataset used in IREX III with one notable
exception: The images in the current dataset were never compressed, while the vast majority of those in the
original OPS dataset had been previously compressed using JPEG at a quality setting of 75.

155 The OPS-II consists of several million operational images collected from 18 distinct commercial iris cameras.
Some subjects' irides were captured by more than one camera model. Most of the iris images have a pixel res-
olution of 640x480, but some are 480x480. NIST intends to exclude the pathological 330x330 images discussed
in IREX III from this evaluation. Some of the non-pathological images still have poor sample quality (e.g. high
amounts of occlusion, specular reflections, heavy pupillary constriction). Some were captured outside and con-
tain heavily constricted pupils. See the IREX III Supplement I [2] for more information. Search and enrollment
samples will be pulled from the same source and will therefore be of comparable quality.

156 2.2.2 Ground Truth Integrity

157 A hazard with collecting operational data is that ground truth identity labels can be incorrectly assigned due to
158 clerical error. A Type I error occurs when a person's iris image is present under two or more identities. To correct
159 for this type of error during evaluation, NIST will estimate FPIR using search images that have been horizontally
160 flipped¹. The effect of flipping is discussed in the IREX III report. Type II errors occur when two or more persons
161 are assigned the same subject identifier, which can lead to apparent false negatives. NIST cannot correct for this
162 type of error, but analyses in IREX III and its supplement indicate that Type II errors accounted for only a small
163 fraction of the false negatives that occurred when the algorithms were tested over the OPS dataset.

164 2.3 Test Environment

165 2.3.0.1 Hardware Specifications

166 The test machines are high-end PC-class blades, each having 4 CPUs with 4 cores per CPU. The blades are
167 labeled Dell M905, equipped with 4x Qual Core AMD Opteron 8376HE processors² running at 2.3GHz. Each
168 CPU has 512K of cache. The bus runs at 667 MHz. Main memory consists of 192GB as 24 8GB modules.
169 Sixteen processes can run without time slicing. NIST may use some test machines that have slightly different
170 hardware specifications, but the operating system and compilation environment will remain homogenous across
171 all blades. Furthermore, timing statistics will only be computed on machines having the aforementioned hardware
172 specifications.

173 2.3.0.2 Operating System

174 The test machines will have CentOS 6.2 installed, which runs Linux kernel 2.6.32-220.7.1 (<http://www.centos.org/>).
175 An ISO image of the distribution can be downloaded from NIGOS (http://nigos.nist.gov:8080/evaluations/CentOS-6.2-x86_64-bin-DVD1.iso).

¹Using the *jpegtran* application provided by the Independent JPEG Group, present on most LINUX platforms.

²`cat /proc/cpuinfo` returns `fpu vme de pse tsc msr pae mce cx8 apic mtrr pge mca cmov pat
npse36 clflush mmx fxsr sse sse2 ht syscall nx pni`

176 2.4 Reporting of Results

177 2.4.1 Final Report

178 Following completion of the testing, NIST will publish one or more Interagency Reports (IRs) on the results. NIST
179 may also use the results to publish in other academic journals or present at conferences or workshops.

180 2.4.2 Interim Reports

181 NIST will provide participants with "score-card" performance results prior to the release of the final report. These
interim reports will be sent as they become available, so participants who submit earlier are more likely to receive
their results sooner. NIST expects the turn-around time to be about two weeks. A participant may submit one pair
of Class P and Class N libraries followed by another pair after receipt of the interim report. To receive an interim
report, the submission must be received by **June 28, 2012**.

182 While the score cards can be used by the participants for arbitrary purposes, they are intended to promote develop-
183 ment and to provide the participants with a faster turnaround on how well their implementations performed. Score
184 cards will be auto-generated for each implementation and will 1) include timing, accuracy, and other performance
185 statistics, 2) include results from other participants without identifying them, 3) be expanded and modified as addi-
186 tional analyses are performed, and 4) be released asynchronously with implementation submissions. NIST does
187 not intend to release the score cards publicly, though it may show them to U.S. government test sponsors. While
188 the score cards are not intended for wider distribution, NIST can only request that sponsoring agencies not release
189 their content.

190 3 Software Submission

191 3.1 Participation Requirements

192 Participation is open to any commercial organization or academic institution that has the ability to implement a
193 large-scale one-to-many iris identification algorithm. There is no charge and participation is open worldwide.

194 The following rules apply:

- 195 • Participants must complete and submit the Participation Agreement
(http://biometrics.nist.gov/cs_links/iris/irexIV/IREX_IV_Application_v1.pdf).
- 196 • Participants must submit at least one Class P, and one Class N, implementation.
- 197 • Participants are permitted to submit up to two Class N and two Class P implementations (so up to four
submissions in total are permitted).
- 198 • Participants must adhere to the cryptographic protection procedures when submitting their implementations
199 (see Section 3.2).
- 200 • All implementations must successfully validate to ensure their proper operation.

201 3.2 Submission Procedure

202 All software, data, and configuration files submitted to NIST must be signed and encrypted. Signing is performed to
203 ensure authenticity of the submission (i.e. that it actually belongs to the participant). Encryption is performed to en-
204 sure privacy. The full process is described at http://biometrics.nist.gov/cs_links/iris/irex/NIST_biometrics_crypto.pdf.

205 *Note: NIST will not accept any submissions that are not signed and encrypted. NIST accepts no responsibility for*

206 anything that occurs as a result of receiving files that are not encrypted with the NIST public key.

207 Implementations shall be submitted to NIST as encrypted *gpg* files. If the encrypted implementation is below 20MB,
208 it can be emailed directly to NIST at irex@nist.gov. If the encrypted implementation is above 20MB, it can either be
209 provided to NIST as a download from a webserver³, or mailed as a CD/DVD to the following address:

210 IREX IV Test Liason (A214)
211 100 Bureau Drive
212 A214/Tech225/Stop 8940
213 NIST
214 Gaithersburg, MD 20899-8940
215 USA

216 Upon receipt, NIST will validate the implementation to ensure its correct operation. The validation process involves
217 running the implementation over a small sample of test data. This test data will be provided to the participant, who
218 must run the implementation in-house and provide NIST with the comparison results. NIST will then verify that
219 the participant's in-house results are consistent with the output produced on the NIST blades. The test data along
220 with full instructions will be posted on the IREX IV homepage (<http://www.nist.gov/itl/iad/ig/irexiv.cfm>) as part of a
221 validation suite.

222 3.3 Requirements for Library Submissions

223 Participants shall provide NIST will pre-compiled and linkable libraries. Dynamic libraries are permitted, but static
224 ones are preferred. Participants shall *not* provide any source code. Header files should not be necessary, but if
225 provided, should not contain intellectual property of the company nor any material that is otherwise proprietary.

226 At least one "core" library must be submitted that adheres to the API specification in section 4.2. This library shall
227 adhere to the naming convention described in Table 6. Additional dynamic or shared library files may be submitted
228 that support this core library.

Table 6: Naming convention for an implementation library.

Form:	libIREX_provider_class_sequence.suffix				
Part:	libIREX	provider	classes	sequence	suffix
Description:	First part of the name, fixed for all submissions	a single word name of the main provider. <i>EXAMPLE:</i> thebes	Functional class described in Table 5 (N or P).	A two-digit decimal identifier starting at 00 and incrementing any time a new submission is sent to NIST	Either .so or .a
Example:	libIREX_thebes_N_03.a				

229 Implementation libraries must be 64-bit. This will support large memory allocations that are necessary when an
230 enrollment database contains millions of entries. To achieve faster running times, NIST expects implementations
231 will load the enrollment templates into main memory before the enrollment database is searched. It is safe to
232 assume that NIST will not build enrollment databases containing more than 10 million entries (generated from 10
233 million iris samples). This means that template sizes should not exceed ~19K on average.

234 NIST will ignore requests to alter parameters by hand (e.g. modify specific lines in an XML configuration file). Any
235 such adjustments must be submitted as a new implementation.

³NIST shall not be required to register or enroll in any kind of membership before downloading the implementation.

236 3.4 Linking Requirements

237 NIST will link the submitted library file(s) to our ISO 98/99 C/C++ language test drivers. Participants are required
238 to provide their libraries in a format that is linkable using `gcc version 4.4.6`. The standard libraries are:

- 239 • `/usr/lib64/libstdc++.so.6.0.13` (GLIBCXX 3.4.13)
- 240 • `/lib/libc.so.6 -> libc-2.12.so` (GLIBC 2.12)
- 241 • `/lib/libm.so.6 -> libm-2.12.so`

242 Participants may provide customized command-line linking parameters. A typical link line might be:

```
243 gcc -I. -Wall -m64 -o irex_main irex_main.c -L. -lirex_thebes_N_01 -lpthread
```

244 Participants are strongly advised to verify library-level compatibility with gcc (on an equivalent platform) prior to
245 submitting their software to NIST to avoid linkage problems (e.g. symbol name and calling convention mis-
246 matches, incorrect binary file formats, etc.). Intel ICC is not available. Access to GPUs is not permitted.

247 Intel Integrated Performance Primitives (IPP) libraries are permitted if they are delivered as part of the developer-
supplied library package. It is the provider's responsibility to establish proper licensing of all libraries.

248 On request, NIST will allow the use of g++ for linking, but the library must export its functions according to the C
249 linkage specified in the API. The Standard C++ library is available.

250 Dependencies on external dynamic/shared libraries such as compiler-specific development environment libraries
251 are discouraged. If absolutely necessary, external libraries must be provided to NIST after receiving prior approval
252 from the test liaison. Image processing libraries such as libpng and NetPbm should not be required since NIST will
253 handle image reading and decompression.

254 *IMPORTANT: Windows machines will not be used for testing. Windows-compiled libraries are not permitted. All*
255 *software must run under LINUX.*

256 3.5 Single-thread Requirement

257 Implementations must run in single-threaded mode. Multithreading was supported in IREX III, but all participants
eventually chose to submit single-threaded implementations during the latter stages of phased testing.

258 3.6 Installation Requirements

259 3.6.1 Installation Must be Simple

260 Installation shall require the simple copying of files followed by a linking operation. There shall be no need for
261 interaction with the participant provided everything goes smoothly. It shall not require an installation program.

262 3.6.2 No License Requirements or Usage Restrictions

263 The implementation shall allow itself to be executed on any number of machines without the need for machine-
264 specific license control procedures or activation. The implementation shall neither implement nor enforce any usage
265 controls or restrictions based on licenses, number of executions, presence of temporary files, etc. No activation
266 dongles or other hardware shall be required. The implementations shall remain operable until at least October 31st,
267 2013.

268 3.6.3 Sufficient Documentation Must be Provided

269 Participants shall provide complete documentation of their implementations and detail any additional functionality
270 or behavior beyond those specified here. The documentation must define all (non-zero) vendor-defined error or

271 warning return codes.

272 **3.6.4 Disk-Space Limitations**

273 The implementation may use configuration files and supporting data files. The total size of all libraries and config-
274 uration and data files shall be no more than a gigabyte.

275 **3.7 Runtime Behavior Requirements**

276 *NOTE: If an implementation is buggy or does not comply with these requirements, NIST may not test or report*
277 *results for the implementation in publications.*

278 **3.7.1 No writing to Standard Error or Standard Output**

279 The implementation will be tested in a non-interactive "batch" mode without terminal support. Thus, the submitted
280 library shall run quietly (i.e. it should not write messages to "standard error" or "standard output". An implementation
281 may write debugging messages to a log file. This log file must be declared in the documentation.

282 **3.7.2 Exception Handling Should be Supported**

283 The implementation should support error/exception handling so that, in the case of an unexpected error, a return
284 code is still provided to the calling application. The NIST test harness will gracefully terminate itself if it receives an
285 unexpected return code, as it usually indicates improper operation of the implementation.

286 **3.7.3 No External Communication**

287 Implementations running on NIST hosts shall not side-effect the runtime environment in any manner except through
288 the allocation and release of memory. Implementations shall not write any data to an external resource (e.g. a
289 server, connection, or other process). Implementations shall not attempt to read any resource other than those
290 explicitly allowed in this document. If detected, NIST reserves the right to cease evaluation of the software, notify
291 the participant, and document the activity in published reports.

292 **3.7.4 Components Must be Stateless**

293 All implementation components shall be "stateless" except as noted elsewhere in this document. This applies to
294 iris detection, feature extraction and matching. Thus, all functions should give identical output, for a given input,
295 independent of the runtime history. NIST will institute appropriate tests to detect stateful behavior. If detected, NIST
296 reserves the right to cease evaluation of the software, notify the participant, and document the activity in published
297 reports.

298 **3.7.5 No Switches or Command-line Options**

299 Each implementation must be capable of running stand-alone (i.e. no two submissions shall depend on the same
300 copies of libraries or configuration files). Each implementation shall support only one "mode" of operation. NIST
301 will not entertain the option to "flip a switch" or modify a configuration file to produce a new implementation. Rather,
302 the participant must submit each "mode" as a separate implementation.

303 **3.7.6 Handling Large Enrollment Templates**

304 Enrollment templates should not require more than 200K of persistent storage, on average, per enrolled image.
305 Participants should inform NIST if their implementations require more than 100K of persistent storage.

306 3.7.7 Minimum Speed Requirements

307 The implementations shall perform operations within the time constraints specified by Table 7. These time limits
 308 apply to the function call invocations defined in Section 7. Since NIST cannot regulate the maximum runtime per
 309 operation, limitations are specified as 90th percentiles (i.e. 90% of all calls to the function shall complete in less
 310 time than the specified duration). The limitations assume each template was generated from a single iris sample.

Table 7: Time limitations for specific operations.

Operaton	Timing Restriction
Creation of an enrollment template from a single 640x480 pixel image	1,000 ms
Creation of an identification template from a single 640x480 pixel image	1,000 ms
Finalization of a 1 million template enrollment database	7,200,000 ms
Search duration on a database of one million templates	20,000 ms

311 3.7.8 Failed Template Generations

312 When the implementation fails to produce an enrollment template, it shall still return a blank template (which can
 313 be zero bytes in length). The template will be included in the manifest like all other enrollment templates, but is not
 314 expected to contain any feature information.

315 4 API Specification

316 4.1 Overview

317 Library submissions must export and properly implement all of the functions defined in this section. The testing
 318 process will proceed in two phases: (1) enrollment, followed by (2) identification. The order in which the test
 319 harness will call the functions is outlined in Table 8.

320 The design reflects the following testing objectives:

- 321 • Support distributed enrollment on multiple machines, with multiple processes running in parallel.
- 322 • Support graceful failure recovery and the ability to log the frequency of errors.
- 323 • Respect the black-box nature of proprietary templates.
- 324 • Provide flexibility and freedom to the participant to use arbitrary algorithms.
- 325 • Support the ability to collect timing statistics for specific operations.
- 326 • Support the ability to collect statistics on template sizes.

Table 8: Program Flow

Stage	Function	Metrics of Interest
-------	----------	---------------------

Enrollment	<p>initialize_enrollment_session() Allows the implementation to perform initialization procedures. Provides the implementation with:</p> <ul style="list-style-type: none"> • advanced notice of the number of individuals and images that will be enrolled. • read-only access to the participant-supplied configuration data directory. • read-only access to the directory where the enrollment database will reside. 	
	<p>convert_multiiris_to_enrollment_template() Generates an enrollment template from one or more images of an individual. The implementation is permitted read-only access to the enrollment directory at this stage. The implementation must be able to handle multiple calls to this function from multiple instances of the calling application.</p>	Statistics on template size and generation time.
	<p>finalize_enrollment() Constructs an enrollment database from the enrollment templates. Templates are provided to the function through a manifest file. The contents of the enrollment directory should be populated with everything that is necessary to perform searches against it. This function allows post-enrollment book-keeping, normalization, and other statistical processing of the templates.</p>	
Pre-search	<p>initialize_feature_extraction_session() Prepares the implementation for the generation of identification templates. The implementation is allowed read-only access to the enrollment directory during this stage.</p>	
	<p>convert_multiiris_to_identification_template() Generates an identification template from one or more images of an individual.</p>	Statistics on template size and generation time.
Search	<p>initialize_identification_session() Prepares the implementation for searches against the enrollment database. The function may read data (e.g. templates) from the enrollment directory and load them into memory.</p>	
	<p>identify_template() Searches a template against the enrollment database and returns a list of candidates.</p>	Statistics on search time and accuracy.
Compression (optional)	<p>convert_raster_to_cropped_and_masked() Converts a raw image to an ISO/IEC 19794-6 Type 7 (cropped and masked) image.</p>	

327 **4.2 Functions**328 **Functions**

- 329 • `int32_t get_pid` (`char *sdk_identifier`, `char *email_address`)
- 330 *Retrieves a self-assigned identifier and contact email address for the software under test.*
- 331 • `int32_t get_max_template_sizes` (`uint32_t *max_enrollment_template_size`, `uint32_t *max_recognition_`
332 `template_size`)
- 333 *Retrieves the maximum (per-image) enrollment and search template sizes.*
- 334 • `int32_t initialize_enrollment_session` (`const char *configuration_location`, `const char *enrollment_directory`,
335 `const uint32_t num_persons`, `const uint32_t num_images`)
- 336 *Initialization function, called once prior to one or more calls to `convert_multiiris_to_enrollment_template()`.*
- 337 • `int32_t convert_multiiris_to_enrollment_template` (`const MULTIIRIS *input_irides`, `MULTISEGMENTATION`
338 `*output_properties`, `uint32_t *template_size`, `uint8_t *proprietary_template`)
- 339 *Generates an enrollment template from a `MULTIIRIS` object.*
- 340 • `int32_t finalize_enrollment` (`const char *enrollment_directory`, `const char *edb_name`, `const char *edb_`
341 `manifest_name`)
- 342 *Finalization function, used to construct an enrollment database from an EDB and its manifest.*
- 343 • `int32_t initialize_feature_extraction_session` (`const char *configuration_location`, `const char *enrollment_`
344 `directory`, `uint64_t *expected_memsize`)
- 345 *Initialization function, to be called once prior to one or more calls to `convert_multiiris_to_identification_template()`.*
- 346 • `int32_t convert_multiiris_to_identification_template` (`const MULTIIRIS *input_irides`, `MULTISEGMENTATIO`
347 `N *output_properties`, `uint32_t *template_size`, `uint8_t *identification_template`)
- 348 *Generates an identification template from a `MULTIIRIS` object.*
- 349 • `int32_t initialize_identification_session` (`const char *configuration_location`, `const char *enrollment_`
350 `directory`)
- 351 *Initialization function, to be called once prior to one or more calls to `identify_template()`.*
- 352 • `int32_t identify_template` (`const uint8_t *identification_template`, `const uint32_t identification_template_size`,
353 `const uint32_t candidate_list_length`, `CANDIDATE *const *candidate_list`, `uint8_t *decision`)
- 354 *Searches a template against the enrollment database and returns a list of candidates.*
- 355 • `int32_t convert_raster_to_cropped_and_masked` (`const ONEIRIS *input_iris`, `ONEIRIS *output_iris`)
- 356 *Convert a raw (640x480 or 480x480) image to an ISO/IEC 19794-6 Type 7 (cropped and masked) image.*

357 **4.2.1 Function Documentation**358 **4.2.1.1 `int32_t get_pid` (`char * sdk_identifier`, `char * email_address`)**

359 Retrieves a self-assigned identifier and contact email address for the software under test.

Parameters

360	out	<code>sdk_identifier</code>	A hexadecimal integer stored as a null terminated ASCII string. The value can be whatever the participant chooses, but must be unique for each implementation. 5 bytes will be pre-allocated for this.
361	out	<code>email_address</code>	The point of contact for the software under test, stored as a null terminated ASCII string. 64 bytes will be pre-allocated for this.

Returns

362 Zero indicates success. Other values indicate a vendor-defined failure.

363 **4.2.1.2 int32_t get_max_template_sizes (uint32_t * max_enrollment_template_size,**
 364 **uint32_t * max_recognition_template_size)**

365 Retrieves the maximum (per-image) enrollment and search template sizes.

366 These values will be used by the test harness to pre-allocate space for template data. For a [MULTIIRIS](#) containing K
 367 images, the test-harness will pre-allocate K times the provided value before calling [convert_multiiris_to_enrollment-](#)
 368 [_template\(\)](#) or [convert_multiiris_to_identification_template\(\)](#).

Parameters

369	out	<i>max_enrollment-</i> <i>_template_size</i>	The maximum (per-image) size of an enrollment template in bytes.
370	out	<i>max_</i> - <i>recognition_</i> - <i>template_size</i>	The maximum (per-image) size of a search template in bytes.

Returns

371 Zero indicates success. Other values indicate a vendor-defined failure.

372 **4.2.1.3 int32_t initialize_enrollment_session (const char * configuration_location,**
 373 **const char * enrollment_directory, const uint32_t num_persons, const uint32_t**
 374 **num_images)**

375 Initialization function, called once prior to one or more calls to [convert_multiiris_to_enrollment_template\(\)](#).

376 The implementation shall tolerate execution of multiple calls to this function from different processes running on the
 377 same machine. Each process may be reading and writing to the enrollment directory.

Parameters

378	in	<i>configuration_</i> - <i>location</i>	Path to a <i>read-only</i> directory containing vendor-supplied configuration parameters and/or runtime data files.
379	in	<i>enrollment_</i> - <i>directory</i>	The directory will be initially empty, but may have been initialized and populated by separate invocations of the enrollment process. The software may populate this folder in any manner it sees fit.
	in	<i>num_persons</i>	The number of persons who will be enrolled in the database.
	in	<i>num_images</i>	The number of images, summed over all identities, that will be used to build the enrollment database.

Returns

Return Value	Meaning
0	Success
2	The configuration data is missing, unreadable, or in an unexpected format.
4	An operation on the enrollment directory failed (e.g. insufficient permissions, insufficient disk-space, etc).
6	The software cannot support the number of persons or images requested
Other	Vendor-defined failure

4.2.1.4 int32_t convert_multiiris_to_enrollment_template (const MULTIIRIS * input_irides, MULTISEGMENTATION * output_properties, uint32_t * template_size, uint8_t * proprietary_template)

Generates an enrollment template from a MULTIIRIS object.

In addition to handling raw OPS-II images, this function must be able to process ISO/IEC 19794-6 Type 7 (cropped and masked) images.

If the function returns a zero exit status, the calling application will store the template in the EDB, which is later be passed to `finalize_enrollment()`. If the function returns a value of 8, NIST will debug. Otherwise, a non-zero return value will indicate a failure to enroll. The template will still be added to the EDB and the manifest to ensure that an N person enrollment database contains N entries. If the function crashes, NIST will include a zero-length template in the EDB and the manifest. The finalization process must be able to process zero-length templates.

IMPORTANT: The implementation shall not attempt to write to the enrollment directory (nor to other resources) during this call. Data collected from the MULTIIRIS object should be stored in the template or created from the templates during the finalization step.

Parameters

in	<i>input_irides</i>	The iris samples from which to generate the template.
out	<i>output_properties</i>	Segmentation and quality information for each iris sample. The NIST test harness will pre-allocate the memory for the ONESEGMENTATION objects (one per ONEIRIS object). The calling application shall <i>NOT</i> initialize this memory.
out	<i>template_size</i>	The size, in bytes, of the output template.
out	<i>proprietary_template</i>	Template generated from the MULTIIRIS object. The template's format is proprietary and NIST will not access any part of it other than to store it in the EDB. The memory for the template will be pre-allocated by the NIST test harness. The implementation shall <i>not</i> allocate this memory.

Returns

Return Value	Meaning
0	Success.
2	Elective refusal to process the MULTIIRIS.
4	Involuntary failure to extract features.
6	Elective refusal to produce a template.
8	Cannot parse the input data.
Other	Vendor-defined failure.

399 **4.2.1.5 int32_t finalize_enrollment (const char * enrollment_directory, const char ***
 400 **edb_name, const char * edb_manifest_name)**

401 Finalization function, used to construct an enrollment database from an EDB and its manifest.

402 Finalization shall be performed after all enrollment processes are complete. It should populate the contents of
 403 the enrollment directory with everything that is necessary to perform searches against it. This function allows
 404 post-enrollment book-keeping, normalization, and other statistical processing of the generated templates. It should
 405 tolerate being called multiple times, although subsequent calls should probably not do anything.

406 The format of the two input files is described in the table below. The enrollment database (EDB) file stores a
 407 concatenation of the templates generated by calls to `convert_multiiris_to_enrollment_template()` in binary format.
 408 It does not contain a header or any delimiters between templates. This file can potentially be several gigabytes
 409 in size. The EDB manifest is an ASCII file that stores information about each template in the EDB file. Each line
 410 contains three space-delimited fields specifying the id, length, and offset of the template in the EDB file. If the EDB
 411 file contains N templates, the manifest will contain N lines.

412 For all intents and purposes, the template id can be regarded as a person id.

Field	Description	Datatype Size
Template ID	Non-negative decimal integer, not necessarily zero-indexed or in any particular order.	4 bytes
Template Length	Non-negative decimal integer.	4 bytes
Offset of template in EDB file	Non-negative decimal integer.	8 bytes
Example:		
901231 1024 0		
5834891 0 1024		
50403 1024 1024		
...		

Parameters

414	in	<i>enrollment_directory</i>	The top-level directory in which the enrollment database will reside. The implementation will have read and write access to this directory.
415	in	<i>edb_name</i>	The path to a single <i>read-only</i> file containing the concatenated templates. - The implementation should extract content from this file and place it in the enrollment directory.
	in	<i>edb_manifest_name</i>	The path to a single <i>read-only</i> file containing the EDB manifest.

Returns

Value	Meaning
0	Success.
2	Cannot locate the input data - the input files or names seem incorrect.
4	An operation on the enrollment directory failed.
6	One or more template files are in an incorrect format.
Other	Vendor-defined failure.

4.2.1.6 `int32_t initialize_feature_extraction_session (const char * configuration_location, const char * enrollment_directory, uint64_t * expected_memsize)`

Initialization function, to be called once prior to one or more calls to `convert_multiiris_to_identification_template()`. The implementation shall tolerate execution of multiple calls to this function from different processes running on the same machine.

Parameters

in	<code>configuration_location</code>	Path to a <i>read-only</i> directory containing vendor-supplied configuration parameters and/or runtime data files.
in	<code>enrollment_directory</code>	The top-level directory in which the enrollment data was placed when <code>finalize_enrollment()</code> was called.
in	<code>expected_memsize</code>	Given the enrollment data, the implementation shall specify the expected or peak memory size (in bytes) that will be used during searching.

Returns

Return Value	Meaning
0	Success.
2	The configuration data is missing, unreadable, or in an unexpected format.
4	An operation on the enrollment directory failed.
Other	Vendor-defined failure.

4.2.1.7 `int32_t convert_multiiris_to_identification_template (const MULTIIRIS * input_irides, MULTISEGMENTATION * output_properties, uint32_t * template_size, uint8_t * identification_template)`

Generates an identification template from a `MULTIIRIS` object.

In addition to handling raw OPS-II images, this function must be able to process ISO/IEC 19794-6 Type 7 (cropped and masked) images.

If the function returns a zero exit status, the template will be used for matching. If the function returns a value of 8, NIST will debug. Otherwise, a non-zero return value will indicate a failure to acquire and the template will *not* be used in subsequent search operations.

Parameters

in	<code>input_irides</code>	The iris samples from which to generate the template.
out	<code>output_properties</code>	Segmentation and quality information for each iris sample. The NIST test harness will pre-allocate the memory for the <code>ONESEGMENTATION</code> objects (one per <code>ONEIRIS</code> object). The implementation shall <i>NOT</i> initialize this memory.

out	<i>output_properties</i>	Segmentation and quality information for each iris sample. The NIST test harness will pre-allocate the memory for the ONESEGMENTATION objects.
out	<i>template_size</i>	The size, in bytes, of the output template
out	<i>identification_template</i>	Template generated from the MULTIIRIS object. The template's format is proprietary and NIST will not access any part of it other to pass it to identify_template() and possibly store it temporarily. The memory for the template will be pre-allocated by the NIST test harness. The implementation shall <i>not</i> allocate this memory.

Returns

Return Value	Meaning
0	Success.
2	Elective refusal to process the MULTIIRIS.
4	Involuntary failure to extract features.
6	Elective refusal to produce a template.
8	Cannot parse the input data.
Other	Vendor-defined failure.

If the [MULTIIRIS](#) contains multiple images, then a zero status should be returned as long as feature information could be extracted from at least one of the images.

4.2.1.8 `int32_t initialize_identification_session (const char * configuration_location, const char * enrollment_directory)`

Initialization function, to be called once prior to one or more calls to [identify_template\(\)](#).

The function may read data (e.g. templates) from the enrollment directory and load them into memory.

Parameters

in	<i>configuration_location</i>	Path to a <i>read-only</i> directory containing vendor-supplied configuration parameters and/or runtime data files.
in	<i>enrollment_directory</i>	The top-level directory in which the enrollment data was placed when finalize_enrollment() was called.

Returns

Return Value	Meaning
0	Success.
Other	Vendor-defined failure.

4.2.1.9 `int32_t identify_template (const uint8_t * identification_template, const uint32_t identification_template_size, const uint32_t candidate_list_length, CANDIDATE *const * candidate_list, uint8_t * decision)`

Searches a template against the enrollment database and returns a list of candidates.

NIST will typically set the candidate list length to operationally feasible values (e.g. 20), but may decide to extend it to values that approach the size of the enrollment database.

Parameters

456	in	<i>identification_template</i>	A template generated by a call to convert_multiiris_to_identification_template() .
457	in	<i>identification_template_size</i>	The size, in bytes, of the template.
	in	<i>candidate_list_length</i>	The length of the candidate list array.
	out	<i>candidate_list</i>	An array (of length <i>candidate_list_length</i>) of pointers to candidates. Each candidate shall be populated by the implementation and shall be sorted in ascending order of distance score (e.g. the most similar entry shall appear first). The candidate list must be populated with sensible values. The memory for the candidates will be pre-allocated by the NIST test harness.
	out	<i>decision</i>	A boolean decision on whether the implementation believes the top ranked candidate matches the identification template (1=yes, 0=no). This decision should attempt to minimize the cost function for the given class type (see Section 2.1.2).

Returns

Return Value	Meaning
0	Success.
2	The input template is defective.
Other	Vendor-defined failure.

4.2.1.10 `int32_t convert_raster_to_cropped_and_masked (const ONEIRIS * input_iris, ONEIRIS * output_iris)`

462 Convert a raw (640x480 or 480x480) image to an ISO/IEC 19794-6 Type 7 (cropped and masked) image.

463 This function shall perform the same operations that were required to generate a KIND 7 record in IREX I. This involves cropping the image and masking the sclera and eyelids with a solid color. As described in ISO/IEC 19794-6, cropping shall provide a margin 0.6R wide on both the left and right sides of the iris. The margin above and below the iris shall be 0.2R. The upper and lower eyelids shall be masked with a color of 128 while the sclera shall be masked with a color of 200. The boundary between the sclera and eyelids shall be smoothed. See ISO/IEC 19794-6 for further description.

464 Implementation of this function is optional. Implementations that do not support cropping and masking shall return a value of 2. Otherwise, a zero exit status indicates success and the image will be used for matching. If the function returns a value of 8, NIST will debug. Other return values shall indicate an error and the output image will not be used for matching.

Parameters

465	in	<i>input_iris</i>	The input iris.
466	out	<i>output_iris</i>	The result of the masking and cropping operations. Memory for the raster data will already have been allocated prior to the function call. The amount of memory allocated will be equal to that of the input iris.

Returns

Return Value	Meaning
0	Success.
2	The implementation does not support this function.
4	Involuntary failure to localize boundaries or perform masking.
6	Elective refusal to produce the output on quality grounds.
8	Cannot parse the input data.
Other	Vendor-defined failure.

5 Supporting Data Structures

This section describes the data structures used by the API.

5.1 CANDIDATE Struct Reference

Defines a structure that holds a single candidate.

Public Attributes

- `uint8_t failed`
Indicates whether the candidate is valid (0=valid, 1-255=invalid).
- `uint32_t template_id`
Template identifier from the enrollment database.
- `double distance_score`
Measure of distance between the searched template and the candidate.
- `double probability`
Estimate of the probability that the biometric data and candidate belong to different persons.

5.1.1 Detailed Description

Defines a structure that holds a single candidate.

5.1.2 Member Data Documentation

5.1.2.1 `uint8_t failed`

Indicates whether the candidate is valid (0=valid, 1-255=invalid).

5.1.2.2 `uint32_t template_id`

Template identifier from the enrollment database.

5.1.2.3 `double distance_score`

Measure of distance between the searched template and the candidate.

Lower scores indicate greater similarity. The distance score must be non-negative, unless the search template is somehow broken, in which case it shall be set to -1.

493 5.1.2.4 double probability

494 Estimate of the probability that the biometric data and candidate belong to *different* persons.

495 Stated differently, it shall be the probability that a comparison between two randomly chosen people would produce
496 a distance score less than or equal to the distance score reported above. If the search template is somehow
497 broken, this value shall be set to -1.

498 5.2 MULTIIRIS Struct Reference

499 Defines a structure that holds an array of irides for a single person.

500 Public Attributes

501 • uint32_t num

502 *Number of irides.*

503 • ONEIRIS** irides

504 *Zero-indexed array of pointers to the irides.*

505 5.2.1 Detailed Description

506 Defines a structure that holds an array of irides for a single person.

507 5.2.2 Member Data Documentation

508 5.2.2.1 uint32_t num

509 Number of irides.

510 5.2.2.2 ONEIRIS** irides

511 Zero-indexed array of pointers to the irides.

512 5.3 MULTISEGMENTATION Struct Reference

513 Defines a structure that holds an array of [ONESEGMENTATION](#) objects.

514 Public Attributes

515 • uint32_t num

516 *Number of [ONESEGMENTATION](#) objects.*

517 • [ONESEGMENTATION](#)** segs

518 *Zero-indexed array of pointers to [ONESEGMENTATION](#) objects.*

519 5.3.1 Detailed Description

520 Defines a structure that holds an array of [ONESEGMENTATION](#) objects.

521 5.3.2 Member Data Documentation

522 5.3.2.1 uint32_t num

523 Number of [ONESEGMENTATION](#) objects.

524 5.3.2.2 ONESEGMENTATION** segs

525 Zero-indexed array of pointers to [ONESEGMENTATION](#) objects.

526 5.4 ONEIRIS Struct Reference

527 Defines a structure that holds a single iris with corresponding attributes.

528 Public Attributes

529 • [uint8_t eye](#)

530 *Eye label (subject's left or right eye).*

531 • [uint16_t image_width](#)

532 *Image width in pixels.*

533 • [uint16_t image_height](#)

534 *Image height in pixels.*

535 • [uint8_t image_type](#)

536 *Image type integer code.*

537 • [uint16_t camera](#)

538 *The camera sensor ID.*

539 • [uint8_t * data](#)

540 *Pointer to image raster data, 8 bits-per-pixel.*

541 5.4.1 Detailed Description

542 Defines a structure that holds a single iris with corresponding attributes.

543 5.4.2 Member Data Documentation

544 5.4.2.1 uint8_t eye

545 Eye label (subject's left or right eye).

546 The eye label information for the OPS-II dataset has proven unreliable and will not be used for testing. This field
547 will always be set to 0, indicating that it is unspecified or unknown.

548 5.4.2.2 uint16_t image_width

549 Image width in pixels.

550 5.4.2.3 uint16_t image_height

551 Image height in pixels.

552 **5.4.2.4 uint8_t image_type**

553 Image type integer code.

554 This field has different meaning in IREX IV than it did IREX III. A value of 0 indicates that the image will be either 640x640 or 480x480 with no geometric constraints on the locations of the pupil or iris boundaries. A value of 7 indicates an ISO/IEC 19794-6 Type 7 (cropped and masked) image, the result of a call to `convert_raster_to_cropped_and_masked()`.

555 **5.4.2.5 uint16_t camera**

556 The camera sensor ID.

557 This field will always be set to 0x0000, meaning that it is either unknown or unspecified.

558 **5.4.2.6 uint8_t* data**

559 Pointer to image raster data, 8 bits-per-pixel.

560 **5.5 ONESEGMENTATION Struct Reference**

561 Defines a structure that holds segmentation and quality information for an iris sample.

562 **Public Attributes**

- 563 • double `iris_radius`
564 *Iris radius in pixels.*
- 565 • uint16_t `iris_center_x`
566 *x coordinate of iris center.*
- 567 • uint16_t `iris_center_y`
568 *y coordinate of iris center.*
- 569 • double `pupil_radius`
570 *Pupil radius in pixels.*
- 571 • uint16_t `pupil_center_x`
572 *x coordinate of pupil center.*
- 573 • uint16_t `pupil_center_y`
574 *y coordinate of iris center.*
- 575 • uint8_t `quality`
576 *Assessment of iris sample quality.*
- 577 • uint8_t `failed`
578 *Indicates whether segmentation of the iris failed (0=success, 1=failed).*

579 **5.5.1 Detailed Description**

580 Defines a structure that holds segmentation and quality information for an iris sample.

581 **5.5.2 Member Data Documentation**582 **5.5.2.1 double iris_radius**

583 Iris radius in pixels.

584 5.5.2.2 uint16_t iris_center_x

585 x coordinate of iris center.

586 5.5.2.3 uint16_t iris_center_y

587 y coordinate of iris center.

588 5.5.2.4 double pupil_radius

589 Pupil radius in pixels.

590 5.5.2.5 uint16_t pupil_center_x

591 x coordinate of pupil center.

592 5.5.2.6 uint16_t pupil_center_y

593 y coordinate of iris center.

594 5.5.2.7 uint8_t quality

595 Assessment of iris sample quality.

596 Quality is a prediction of how well the sample will perform when matched. 254 indicates quality assessment is
597 unsupported. 255 indicates a failed attempt to assign quality. Otherwise, quality values shall range from 0 to 100,
598 with higher values indicating better quality.

599 5.5.2.8 uint8_t failed

600 Indicates whether segmentation of the iris failed (0=success, 1=failed).

601 6 References

602 [1] P. Grother, G.W. Quinn, J.R. Matey, M. Ngan, W. Salamon, G. Fiumara, and C. Watson. IREX: Performance of
603 Iris Identification Algorithms. Technical report, NIST, 2011. 1, 3

604 [2] G. Quinn and P. Grother. IREX III supplement I: Failure analysis. Technical report, NIST, 2011. 3, 7

605 [3] P. Grother, G.W. Quinn, and Jonathan Phillips. Report on the Evaluation of 2D Still-image Face Recognition
606 Algorithms. Technical report, NIST, 2010. 3

607 [4] A. Martin, G. Doddington, T. Kamm, M. Ordowski, and M. Przybocki. The DET curve in assessment of detection
608 task performance. In *Proc. Eurospeech*, pages 1895–1898, 1997. 3

609 [5] R. Bolle, J. Connell, S. Pankanti, N. Ratha, and A. Senior. *Guide to Biometrics*. Springer, 2004. 3

610 [6] H. Drolon, F. Devaux, A. Descampe, Y. Verschuere, D. Janssens, and B. Macq. OpenJPEG. [http://www.
611 openjpeg.org/](http://www.openjpeg.org/). 5

612 [7] David Taubman. Kakadu software. www.kakadusoftware.com. 5

613 [8] E. Tabassi, P. Grother, and W. Salamon. IREX - IQCE performance of iris image quality assessment algorithms.
614 Technical report, NIST, 2011. 6

-
- 615 [9] Patrick Grother and Elham Tabassi. Performance of biometric quality measures. *IEEE Trans. Pattern Anal.*
616 *Mach. Intell*, pages 531–543, 2007. [7](#)