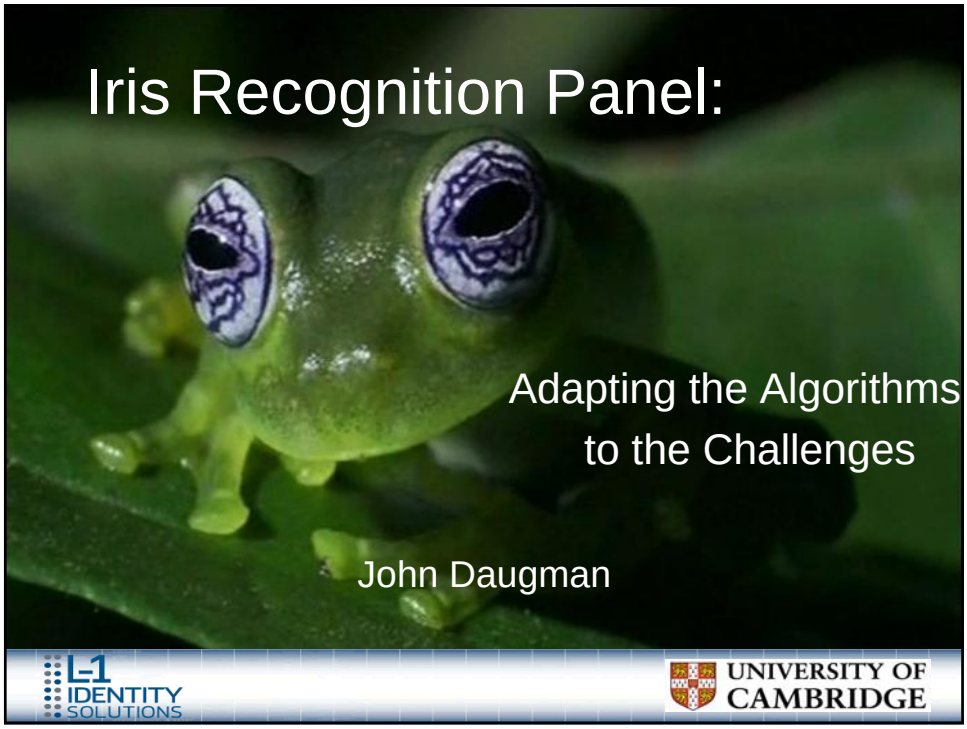
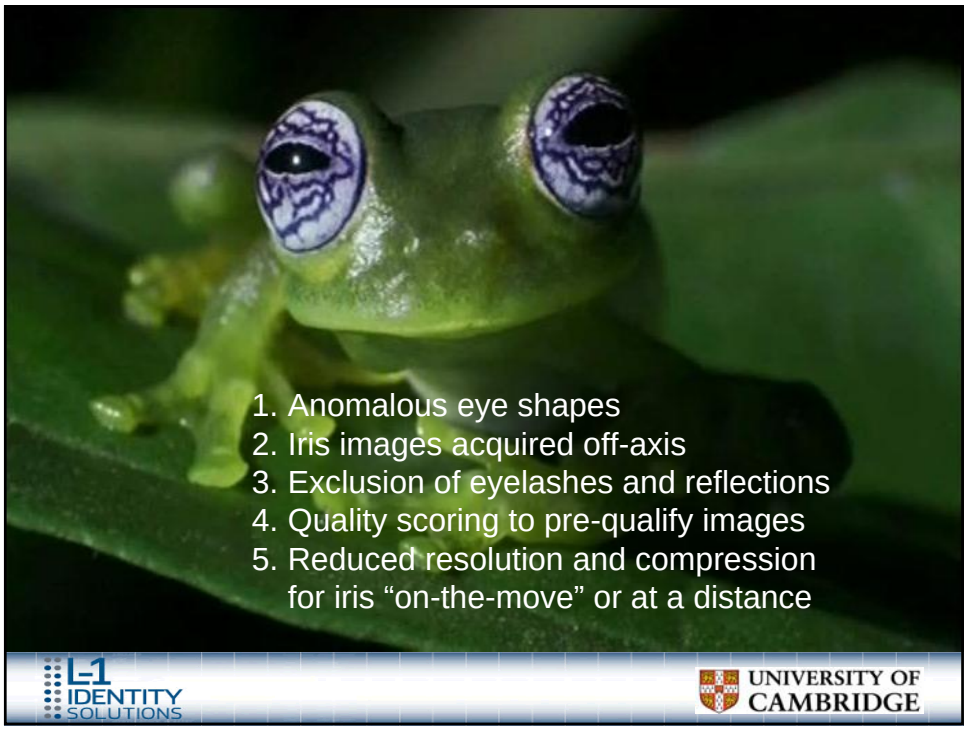
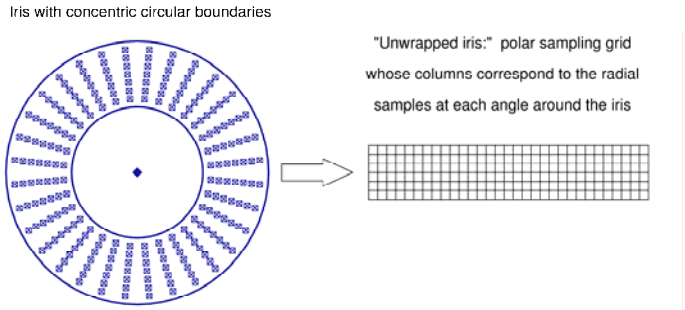

Iris Recognition Panel:
Adapting the Algorithms
to the Challenges
John Daugman
L-1 IDENTITY SOLUTIONS
UNIVERSITY OF CAMBRIDGE

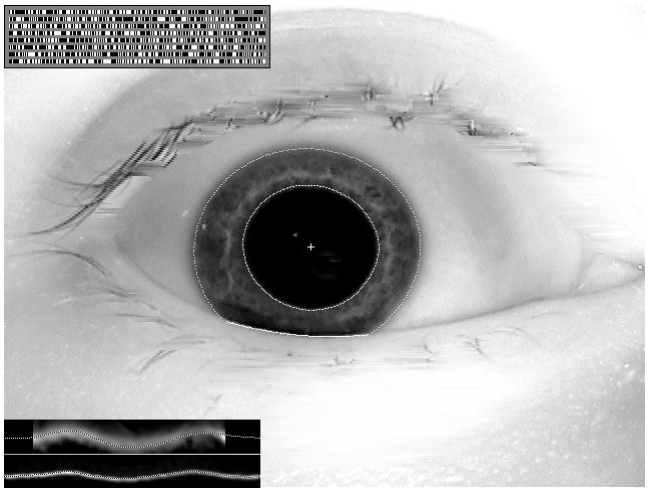

1. Anomalous eye shapes
2. Iris images acquired off-axis
3. Exclusion of eyelashes and reflections
4. Quality scoring to pre-qualify images
5. Reduced resolution and compression
for iris “on-the-move” or at a distance
L-1 IDENTITY SOLUTIONS
UNIVERSITY OF CAMBRIDGE

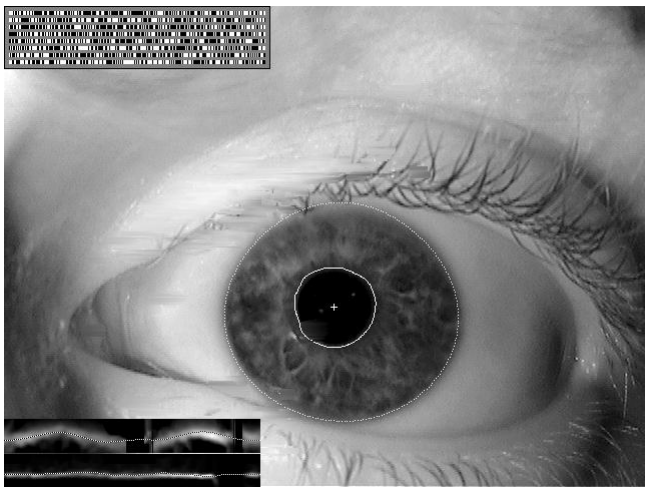
1. Anomalous eye shapes

The “polar unwrapping” approach to iris mapping and normalization makes simplifying assumptions about circular shapes and boundaries



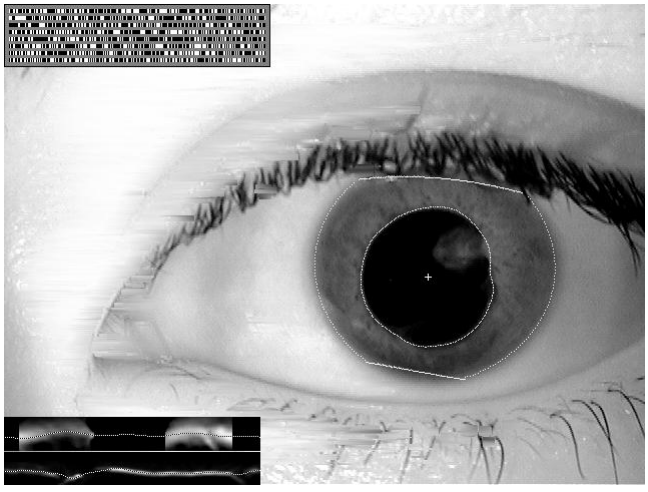
…but these are often not true in reality:





L-1 IDENTITY SOLUTIONS

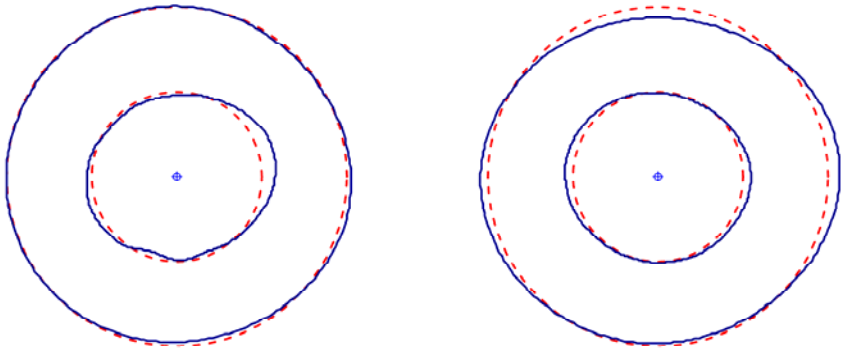
UNIVERSITY OF CAMBRIDGE



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

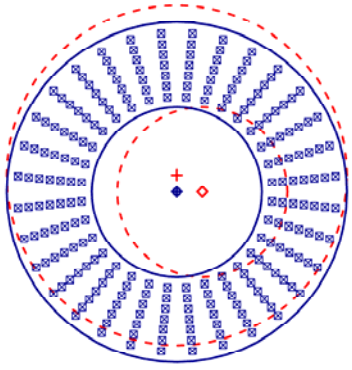
Actual inner and outer boundaries (blue) compared with true circles (red):



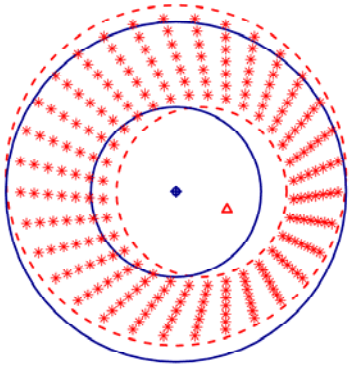
L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

Forcing a circular model creates poor, ambiguous mappings



Mislocalisation of pupil and iris centre

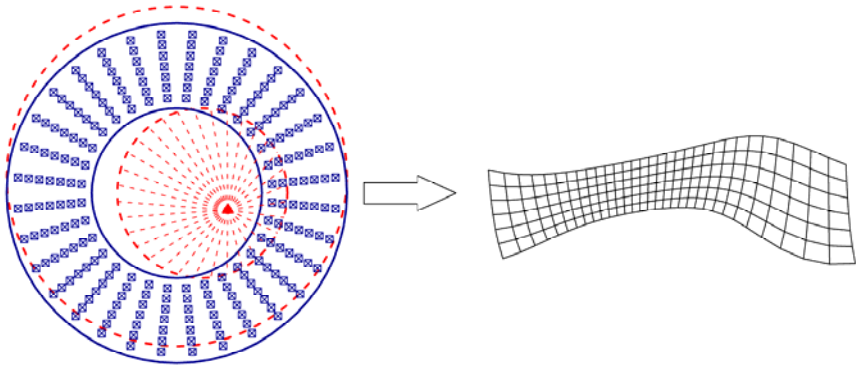


Resulting assignment of the polar grid

L-1 IDENTITY SOLUTIONS

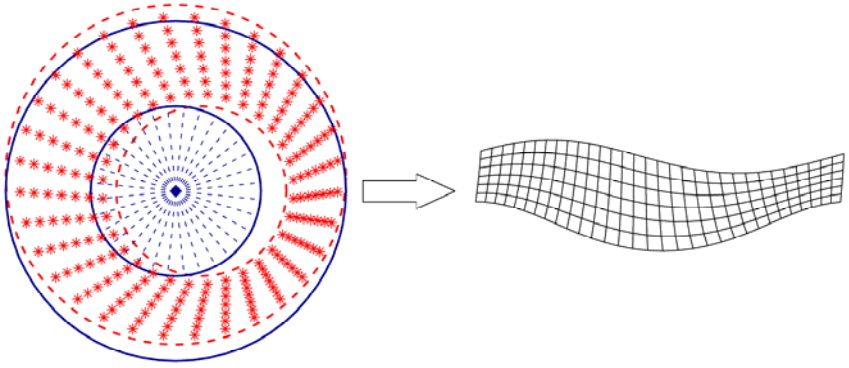
UNIVERSITY OF CAMBRIDGE

…with significant and irrecoverable mapping distortions:



L-1 IDENTITY SOLUTIONS

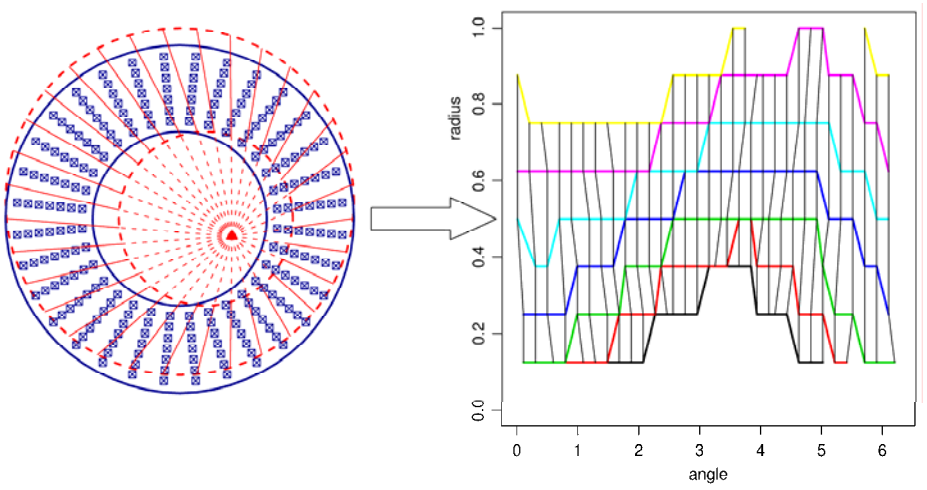
UNIVERSITY OF CAMBRIDGE



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

Bit shift dislocations and higher HD scores are the result.



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

Active Contours and non-Circular Iris Coordinates

- Iris boundaries are rarely true circles. Performance is much enhanced by encoding the boundary shapes accurately when mapping iris patterns.
- So: compute a Fourier expansion of N angular samples of radial gradient edge data $\{r_\theta\}$ for $\theta = 0$ to $N-1$ spanning $[0, 2\pi]$. A set of M discrete Fourier coefficients $\{C_k\}$ are derived from the data sequence $\{r_\theta\}$ as follows:

$$C_k = \sum_{\theta=0}^{N-1} r_\theta e^{-2\pi i k\theta/N}$$

- Note that the zeroth-order coefficient or "DC term" C_0 extracts the average curvature of the boundary: its radius if modelled simply as a circle.
- From these M discrete Fourier coefficients, an approximation to the inner or outer iris boundary (now spanning occlusion interruptions, and at a resolution determined by M) is obtained by the Fourier series $\{R_\theta\}$:

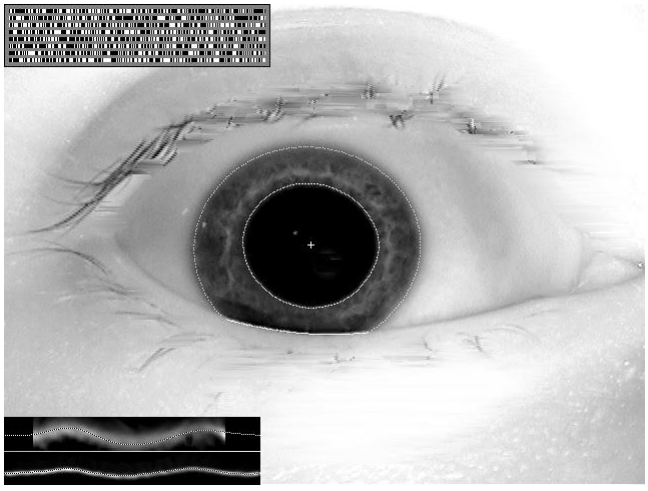
$$R_\theta = \frac{1}{N} \sum_{k=0}^{M-1} C_k e^{2\pi i k\theta/N}$$

- The trade-off between fidelity to the true boundary, and the stiffness of the Active Contour, is set by M, the number of Fourier components used.

L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

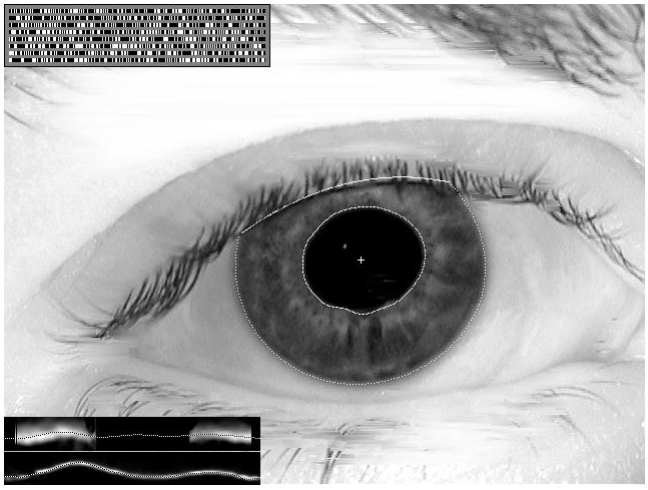
Result of modelling the boundaries with Active Contours



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

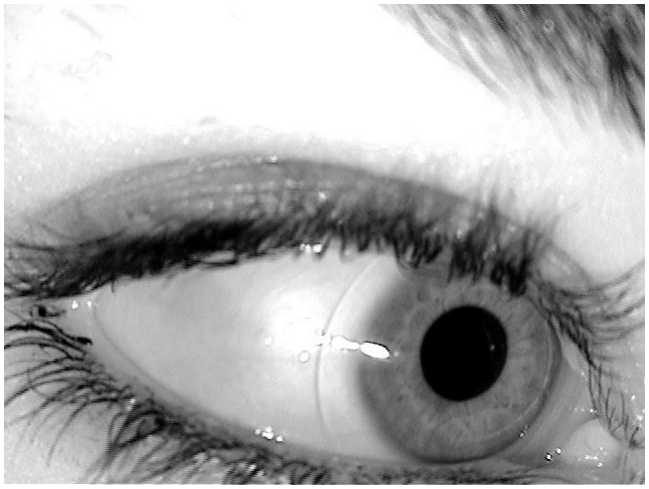
creating a generalized embedded iris coordinate system.



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

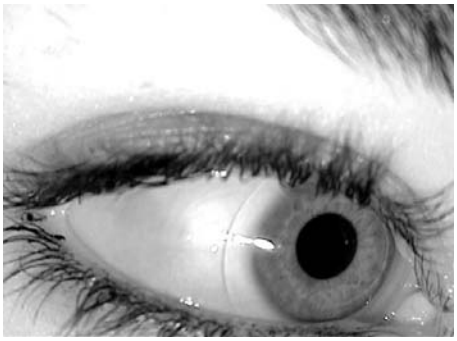
2. Iris images acquired off-axis

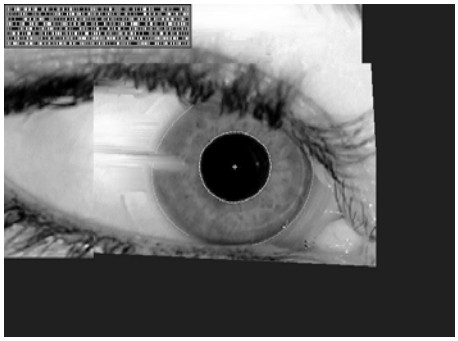


L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

can be “corrected” by Fourier-based trigonometry to estimate the gaze angle and make a corrective affine transformation, effectively “rotating the eye in its socket, towards the camera”

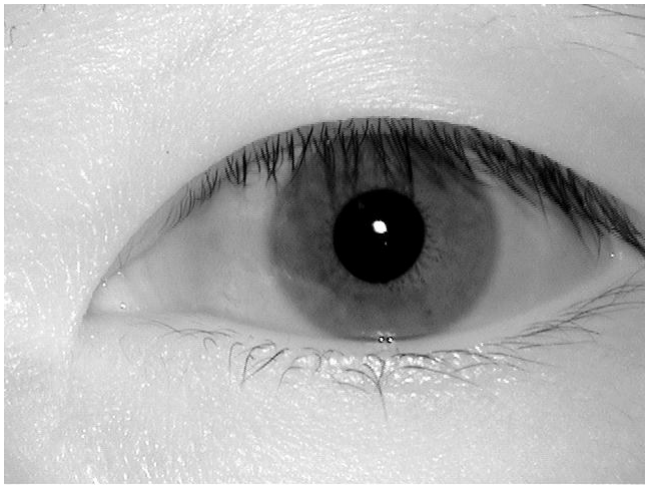




L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

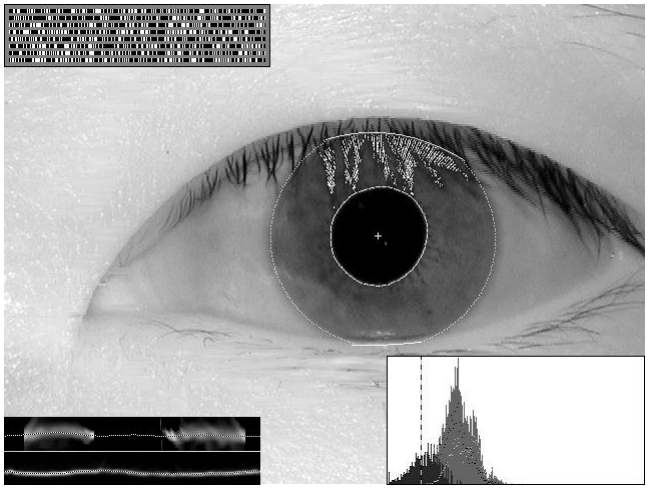
3. Exclusion of eyelashes and reflections



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

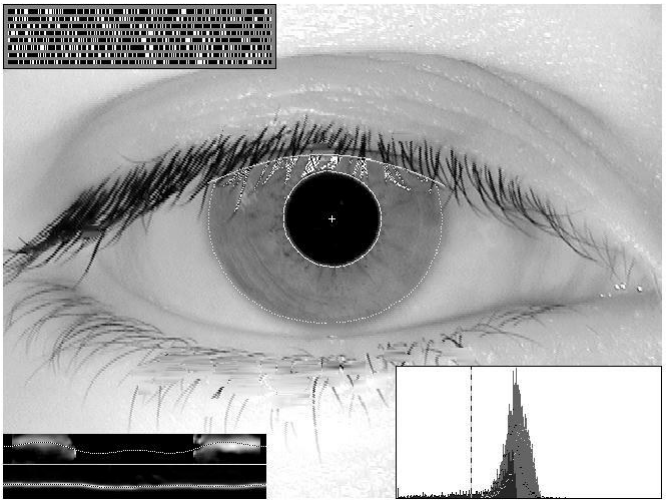
Occluding eyelashes are detected and masked out (prevented from influencing the IrisCode) by statistical



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

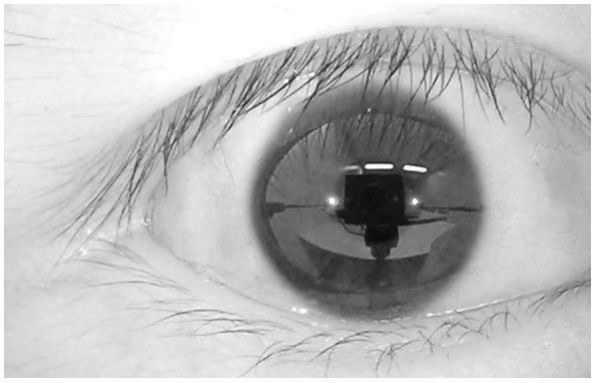
hypothesis testing on the distribution of iris pixels, seeking evidence of a sub-population passing a test.



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

In the visible band of light in unconstrained environments (e.g. outdoors), ambient corneal reflections are common. An iris acquired in the visible band often looks like this:



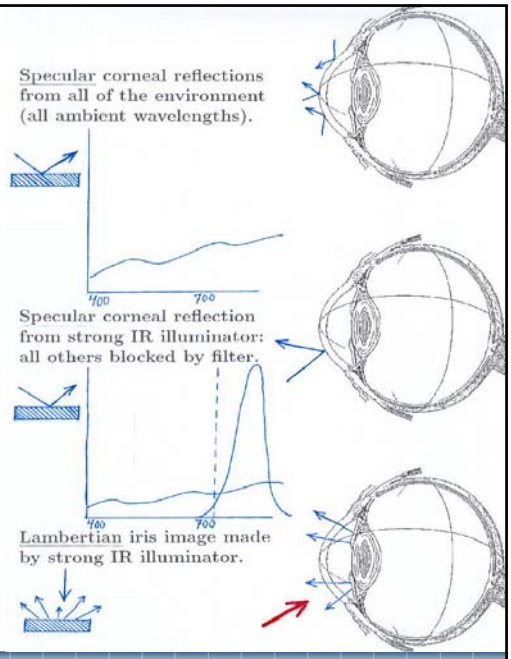
L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

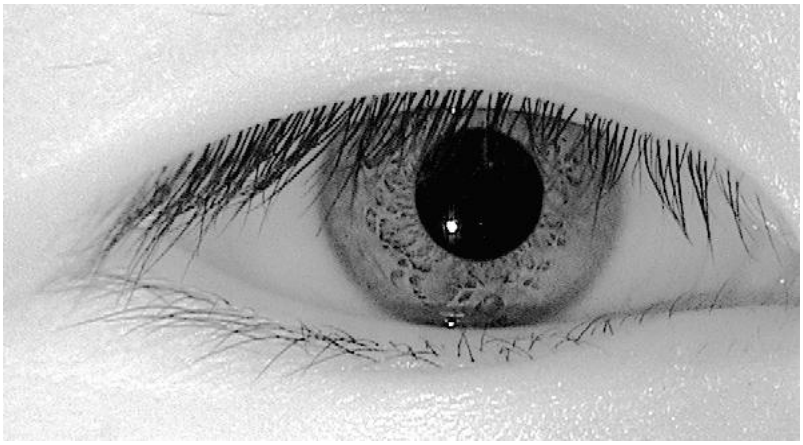
All surfaces lie somewhere between specular (mirror-like) and Lambertian (scattering light equally in all directions).

The cornea is a specular surface; the iris is Lambertian. This fact can be exploited to separate out the ambient environmental corneal reflections, which are broadband but weak, from the more narrow-band light in a nominated band projected by the camera onto the eye to obtain a Lambertian image of the iris.

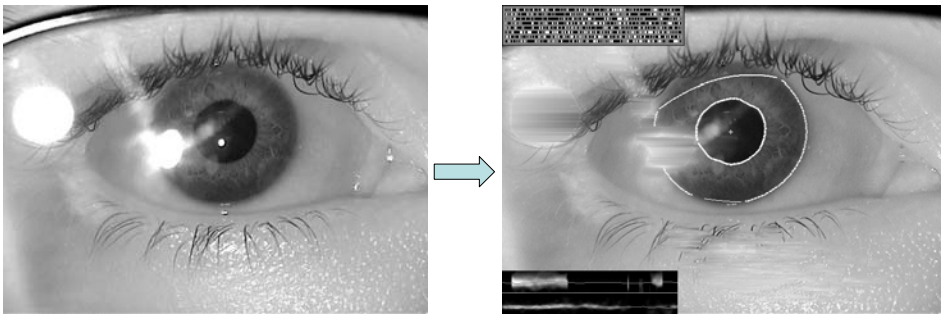
By allowing back into the camera only that same nominated narrow band of light that the iris camera emitted, a band in which there is much more spectral power than in the broadband ambient corneal reflections, these two sources can be separated.



The result is an image acquired in narrowband near-infrared light, from which almost all ambient environmental corneal reflections (except for that of the illuminator) have been “scrubbed.”



Obviously any reflections from eyeglasses must be scrubbed out too, prior to localization of the iris boundaries. If these reflections cover part of the iris, a logical mask must be set to prevent these pixels from influencing the IrisCode, just as with eyelashes and eyelids.

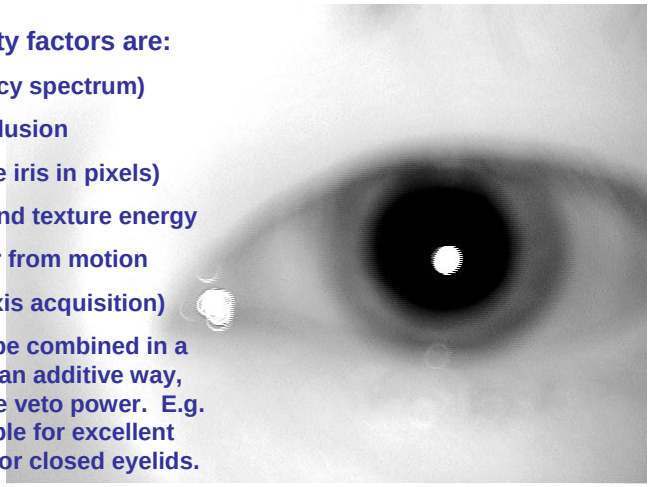


4. Quality scoring to pre-qualify images

Among useful Quality factors are:

- **focus score (frequency spectrum)**
- **amount of eyelid occlusion**
- **resolution (size of the iris in pixels)**
- **boundary contrast, and texture energy**
- **raster interlace shear from motion**
- **gaze deviation (off-axis acquisition)**

These factors should be combined in a logical, not a linear or an additive way, since they should have veto power. E.g. it should not be possible for excellent focus to compensate for closed eyelids.



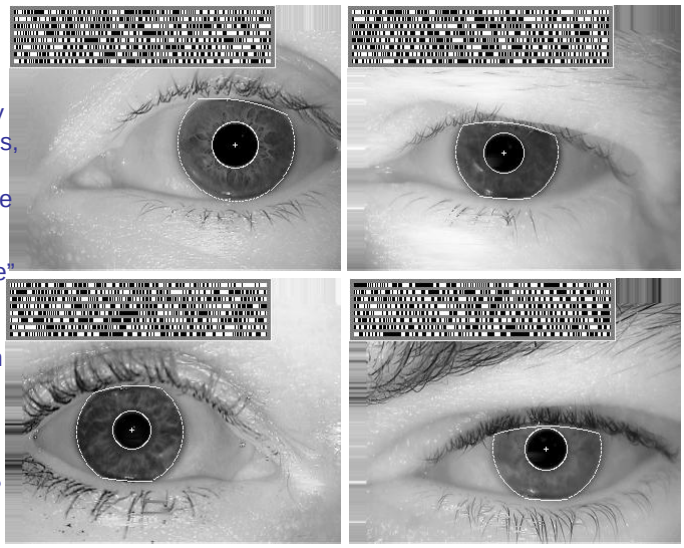
NIST iris test image 242161: Quality Score = **10**/100

5. Reduced resolution and compression

Half-size resolution in QCIF (Quarter Common Intermediate Format), in which the iris radius may typically be only 50 pixels, seems acceptable. No impact on FMR; but there is a small cost in FnMR.

Sarnoff "iris-on-the-move" and "iris-at-a-distance" acquires iris images at this resolution, and then up-samples.

How much farther can reduction in resolution requirement be pushed?

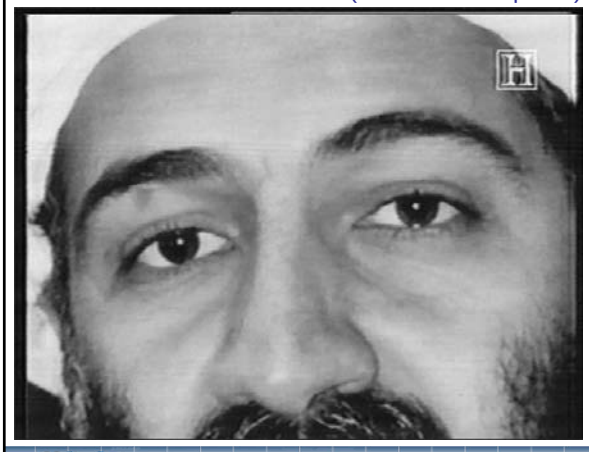


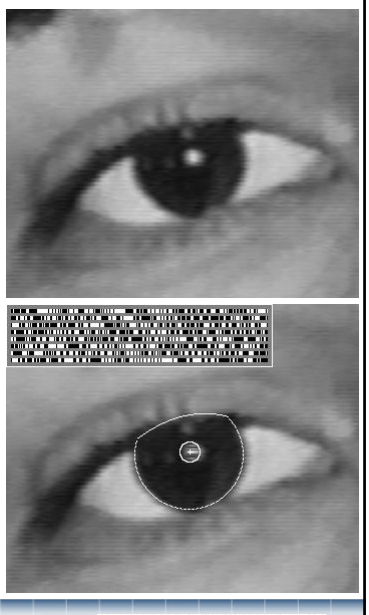
L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

For example, is it reasonable to expect to work at this resolution of iris image acquisition?

(iris radius: 20 pixels)





L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

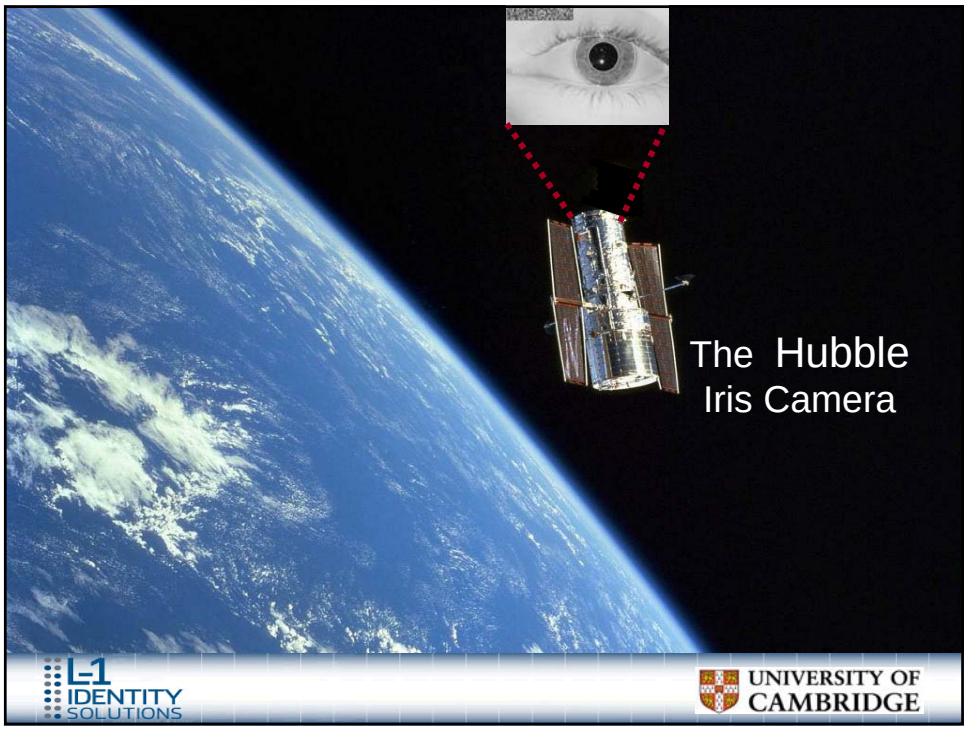
A new synthesis is needed between optics and algorithms ("*algoptics*"?) for co-design of image capture systems and of the algorithms that must recognize the resulting images.

This new discipline is driven by the demands to push the envelop of iris image acquisition ever further:

- IoM - Iris-on-the-Move and Iris-at-a-Distance
- IaS - Iris-across-the-Street ?
- IaT - Iris-across-Town ?
- IfA - Iris-from-the-Air ?

L-1 IDENTITY SOLUTIONS

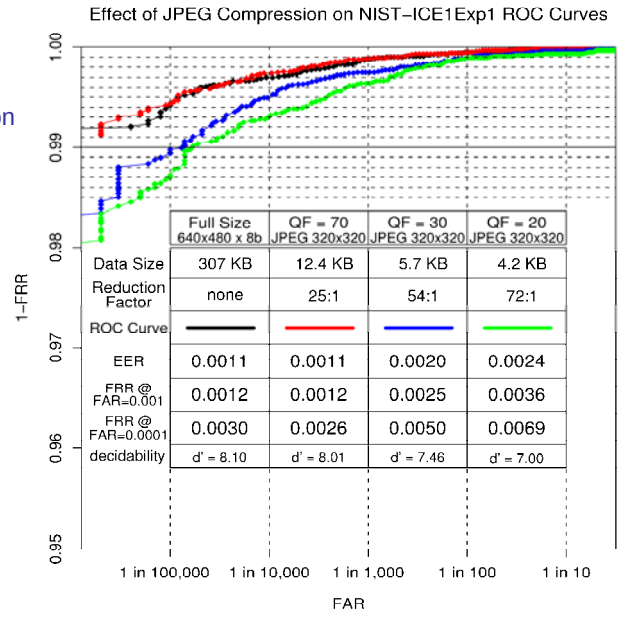
UNIVERSITY OF CAMBRIDGE



L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

Effect of JPEG compression



L-1 IDENTITY SOLUTIONS

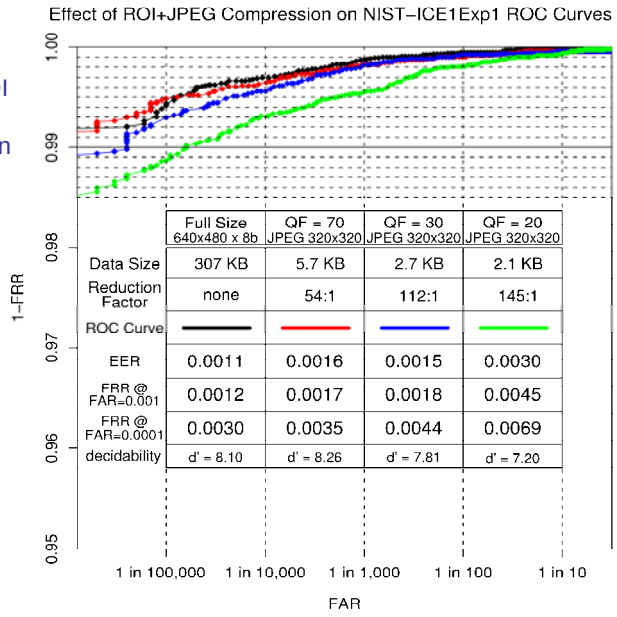
UNIVERSITY OF CAMBRIDGE

Region-of-Interest cropping and JPEG-2000 compression allows iris images to be compressed to only 2,000 – 2,500 bytes with little impact on performance

L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

Effect of JPEG + ROI isolation compression

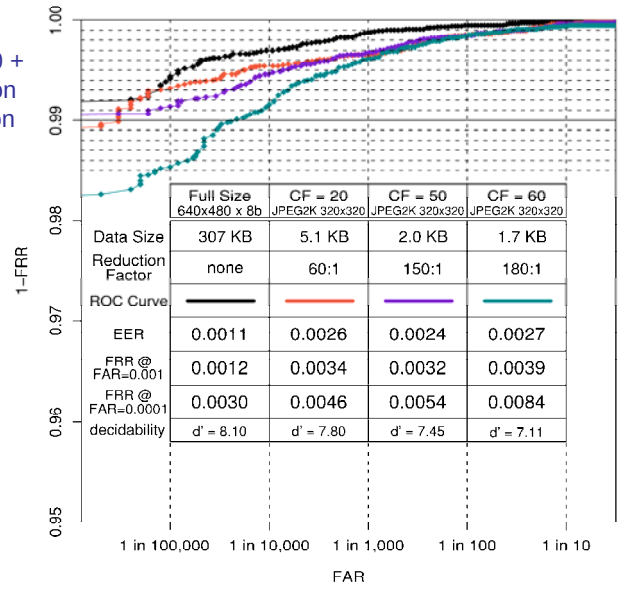


	Full Size 640x480 x 8b	QF = 70 JPEG 320x320	QF = 30 JPEG 320x320	QF = 20 JPEG 320x320
Data Size	307 KB	5.7 KB	2.7 KB	2.1 KB
Reduction Factor	none	54:1	112:1	145:1
ROC Curve				
EER	0.0011	0.0016	0.0015	0.0030
FRR @ FAR=0.001	0.0012	0.0017	0.0018	0.0045
FRR @ FAR=0.0001	0.0030	0.0035	0.0044	0.0069
decidability	d' = 8.10	d' = 8.26	d' = 7.81	d' = 7.20

L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE

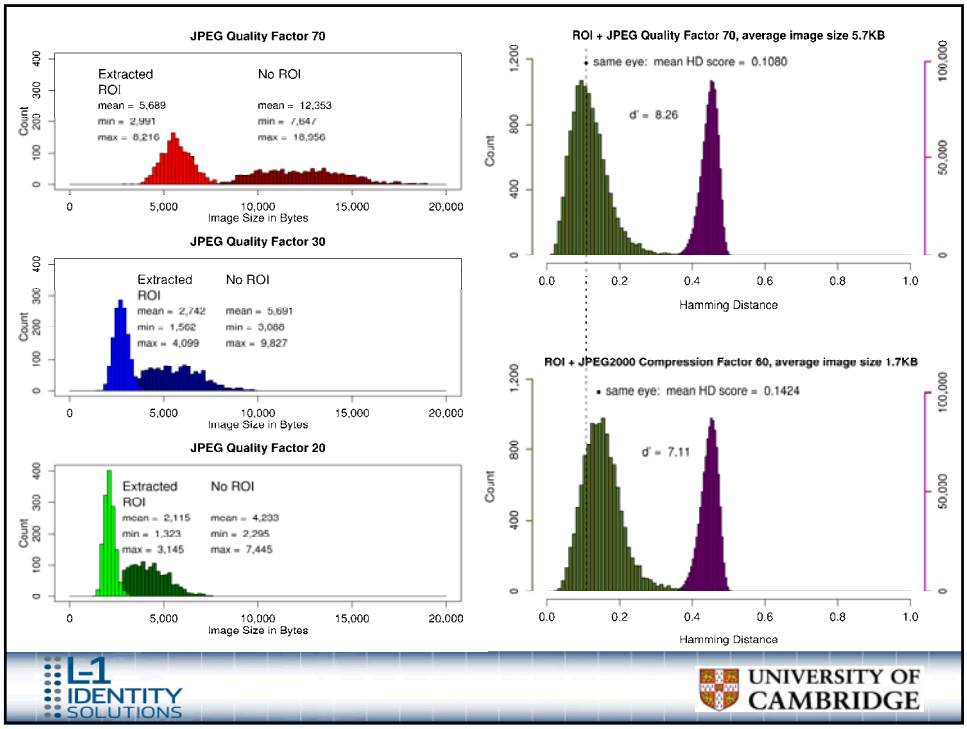
Effect of JPEG-2000 + ROI isolation compression



	Full Size 640x480 x 8b	CF = 20 JPEG2K 320x320	CF = 50 JPEG2K 320x320	CF = 60 JPEG2K 320x320
Data Size	307 KB	5.1 KB	2.0 KB	1.7 KB
Reduction Factor	none	60:1	150:1	180:1
ROC Curve				
EER	0.0011	0.0026	0.0024	0.0027
FRR @ FAR=0.001	0.0012	0.0034	0.0032	0.0039
FRR @ FAR=0.0001	0.0030	0.0046	0.0054	0.0084
decidability	d' = 8.10	d' = 7.80	d' = 7.45	d' = 7.11

L-1 IDENTITY SOLUTIONS

UNIVERSITY OF CAMBRIDGE



Strategy	Compression Parameter	Average Image Size	Interoperability Hamming Distance
Cropping (320 x 320) + JPEG Compression	QF = 70	**12.4 KB**	0.006
	QF = 30	**5.7 KB**	0.011
	QF = 20	**4.2 KB**	0.021
Cropping + ROI + JPEG Compression	QF = 70	**5.7 KB**	0.015
	QF = 30	**2.7 KB**	0.021
	QF = 20	**2.1 KB**	0.031
Cropping + ROI + JPEG2000 Compression	CF = 20	**5.1 KB**	0.018
	CF = 50	**2.0 KB**	0.027
	CF = 60	**1.7 KB**	0.035

Interoperability of the ROI and compression methods, compared with original


Thank you!
http://www.CL.cam.ac.uk/users/jgd1000/
L-1 IDENTITY SOLUTIONS
UNIVERSITY OF CAMBRIDGE