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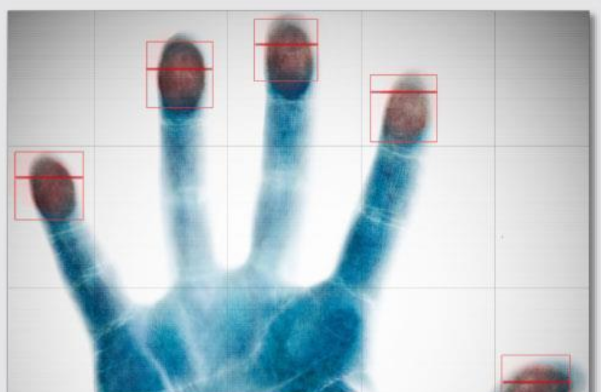
CENTER FOR IDENTIFICATION TECHNOLOGY RESEARCH

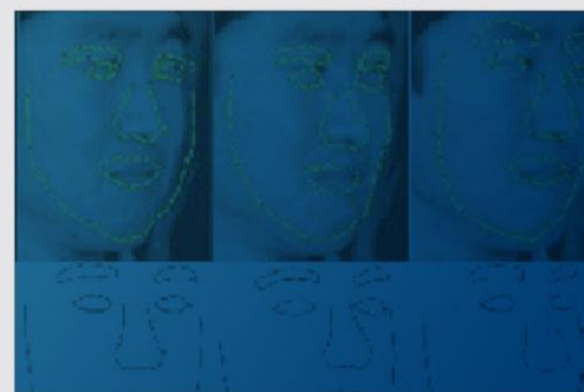
A National Science Foundation Industry/University Cooperative Research Center

Iris—State of Industry

Stephanie Schuckers, Brian Walczak

January 26, 2015





Outline

- Basic Science
  - Modeling
  - Dilation
  - Individuality
  - Permanence
  - Disease
- Performance
  - Cross sensor
  - Quality
  - On the move
  - Distance
  - Mobile
- Security
  - Liveness
  - Contact Lens
- Beyond Iris
  - Ocular
  - Vascular
  - Eye Movement
- Database Sharing

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Modeling

- Generalized model of the eye – called ORNL eye [1]
- Model used to reconstruct off-angle eye to frontal view
- This model takes into consideration the limbus effect
- Synthetic iris dataset created based on eye model, 1056 images

[1] Santos-Villalobos, H, et al. "ORNL biometric eye model for iris recognition." BTAS, 2012.
[2] Karakaya, M, et al. "Limbus impact on off-angle iris degradation." ICB, 2013.

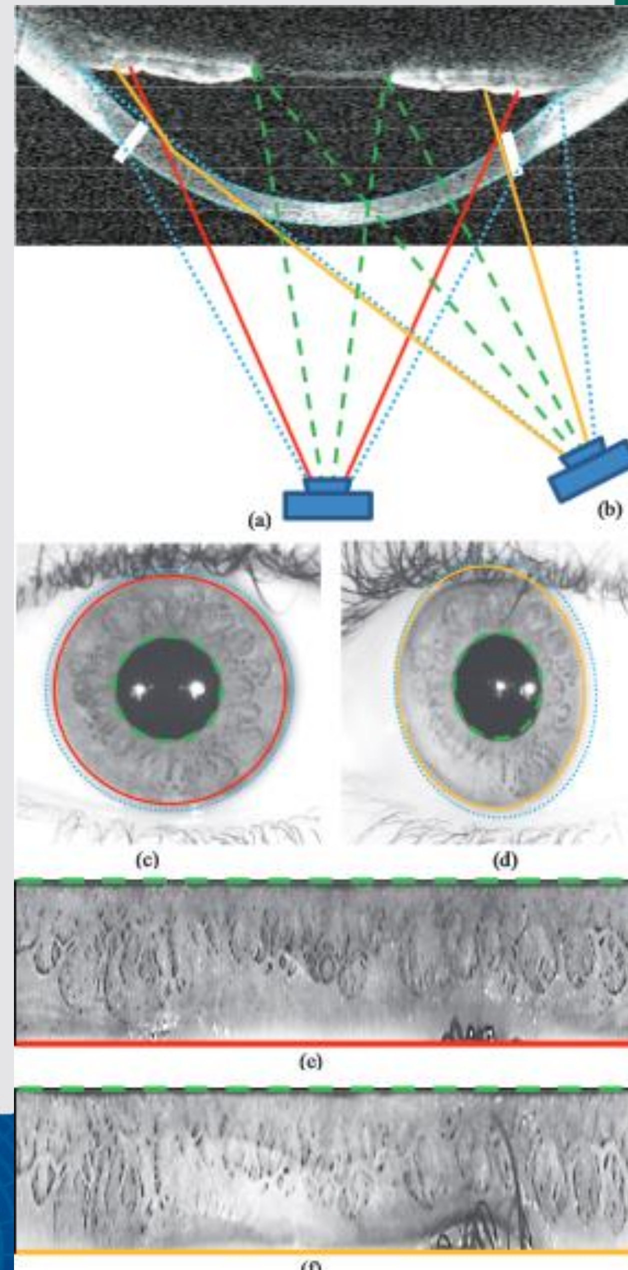
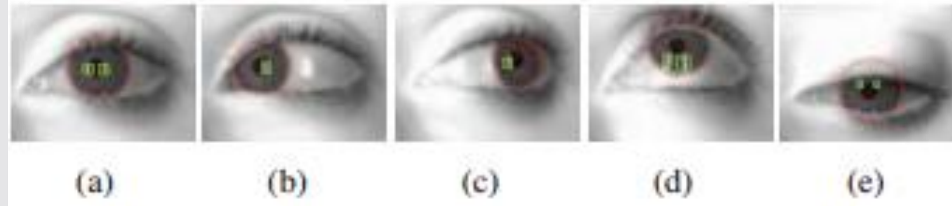


Figure. Illustration of how visible iris region changes with frontal and off-angle. Solid and dotted lines represent actual iris boundaries [2]

Modeling

- Off Angle Estimation & Correction
- Dataset: Clarkson Angle, Q-FIRE, 90 subjects, 24800 images [1, 2]



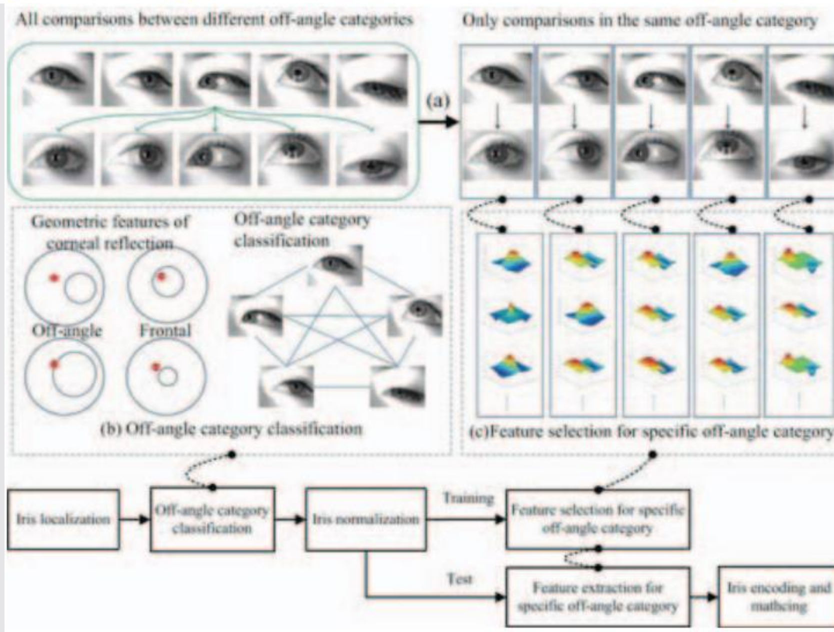


Figure. The flowchart of off-angle iris recognition using Corneal reflections and multiclass SVM

(a) Original acquired image

(c) The reconstructed frontal image.

- Off-angle image is aligned with the model, reprojected to frontal view
- Dataset: 125 images at different camera angles, 25 subjects [3]

[1] Johnson, P. A., et al. "Quality in face and iris research ensemble (Q-FIRE)." BTAS 2010.
[2] Li, Xingguang, et al. "A feature-level solution to off-angle iris recognition." ICB, 2013.
[3] Thompson, Joseph, et al. "Off-angle iris correction using a biological model." BTAS 2013.

Modeling—Iris Curvature

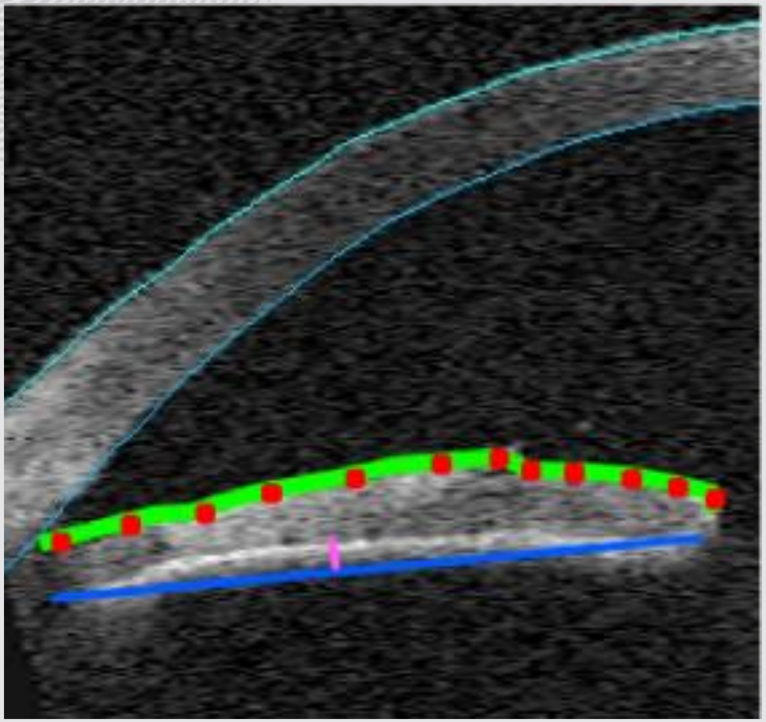


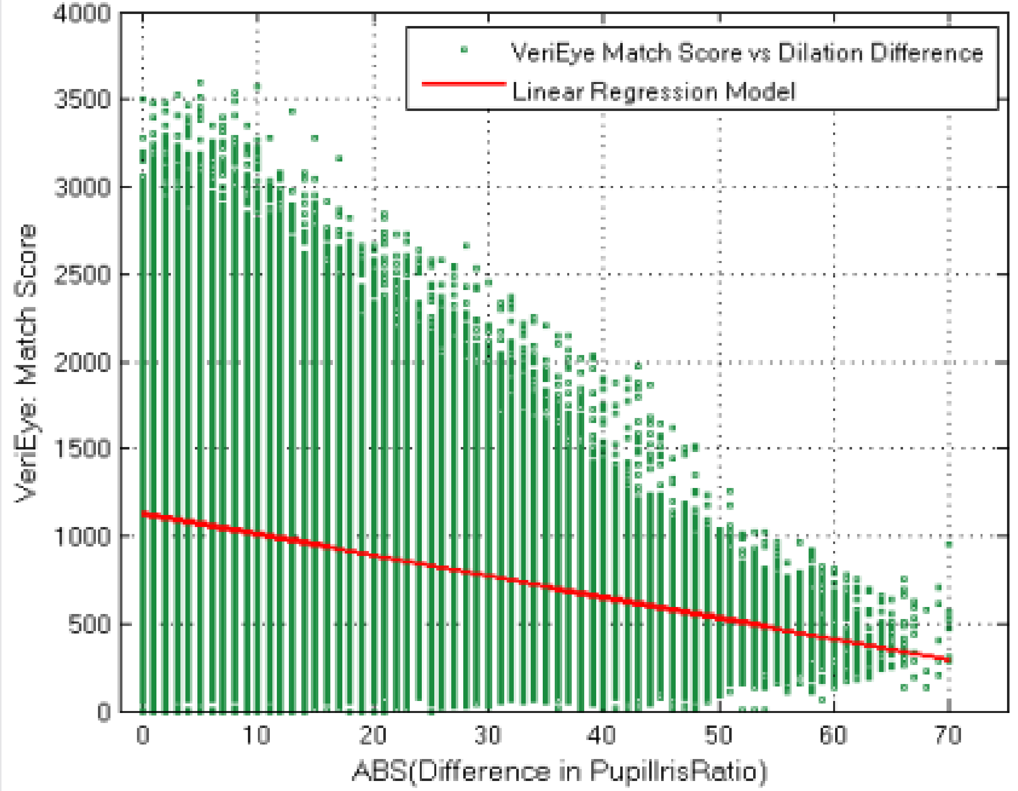
Figure. To generate an iris surface, cubic spline points (red) are defined on the iris surface curve (green) across a meridian. The spline is then revolved about the center of the iris to generate a 3-dimensional surface [1,2]

- Iris curvature measured in order to model the iris shape [2]
- Found that differences in iris curvature degrade matching ability
- Dataset: 201 synthetically generated irises of a single subject

[1] Experimental Eye Research, Vol. 86 / Issue 2. S Dorairaja, et al. Accommodation-induced changes in iris curvature, pp. 220-225. 2008.
[2] Thompson, Joseph, et al. "Effects of iris surface curvature on iris recognition." Biometrics: Theory, Applications and Systems BTAS 2013.

Dilation

- Under alcohol consumption, pupil dilations [1]
- Results show 1 in 5 subjects under the influence may evade identification by iris recognition
- IIT-D Iris under Alcohol Influence database (55 subjects, 220 pre & post alcohol images)
- Difference in pupil dilation can affect iris recognition [2]
- Database: 955 subjects, 49936 eye images



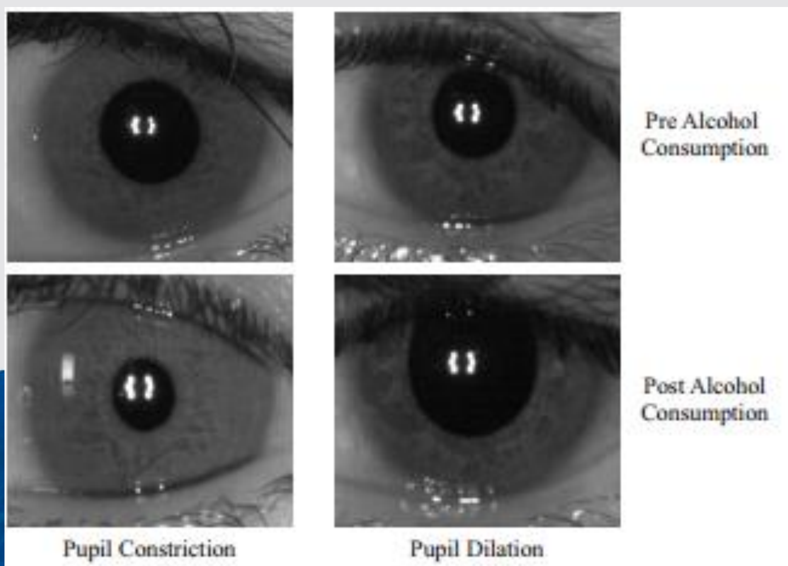
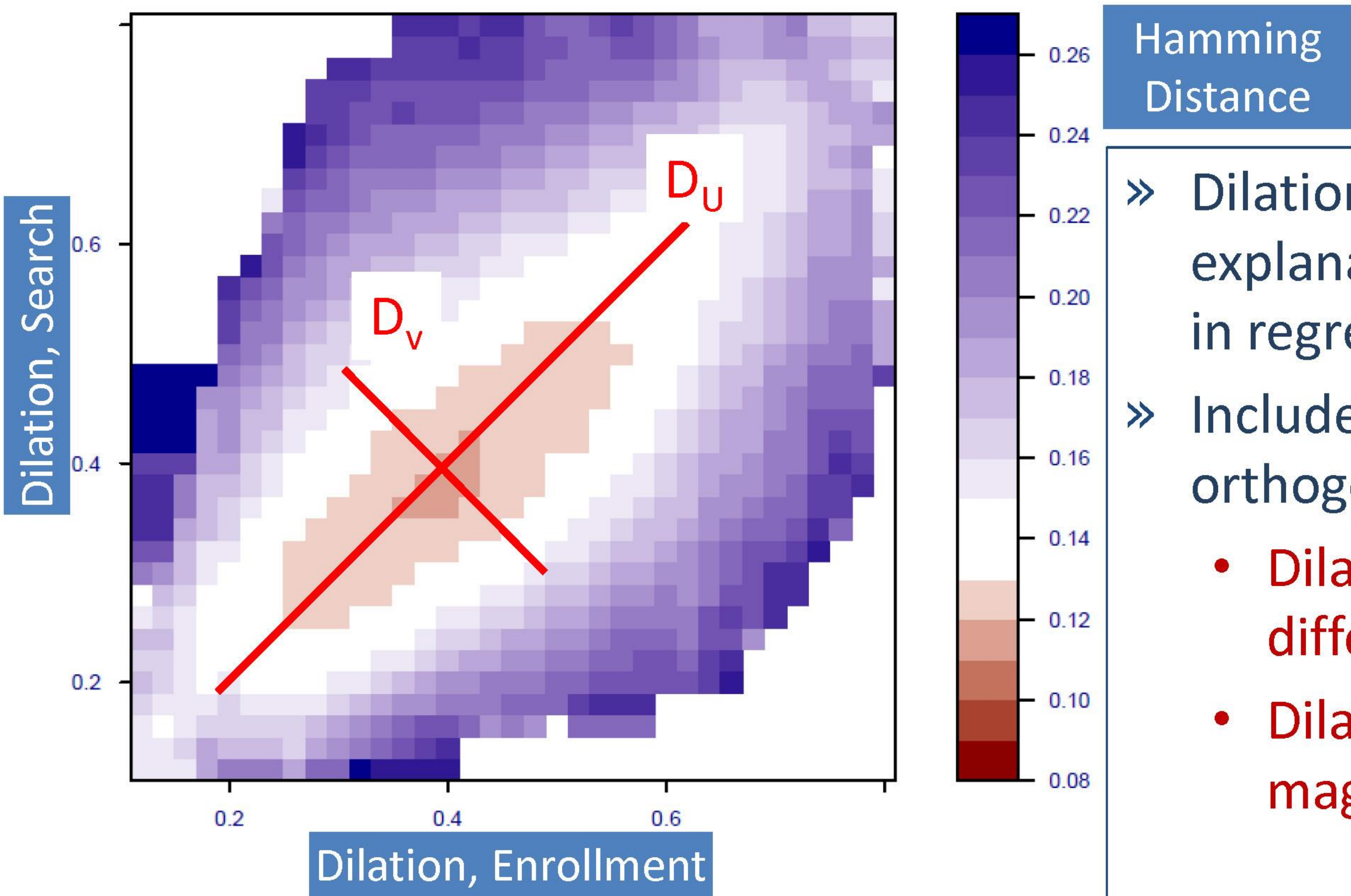


Figure. Examples illustrating constriction and dilation in pupils due to alcohol consumption.

[1] Arora, S, et al. "Iris recognition under alcohol influence: A preliminary study." ICB 2012.
[2] Ortiz, E, et al "A linear regression analysis of the effects of age related pupil dilation change in iris biometrics.“ BTAS 2013.

Accuracy vs. dilation and dilation change



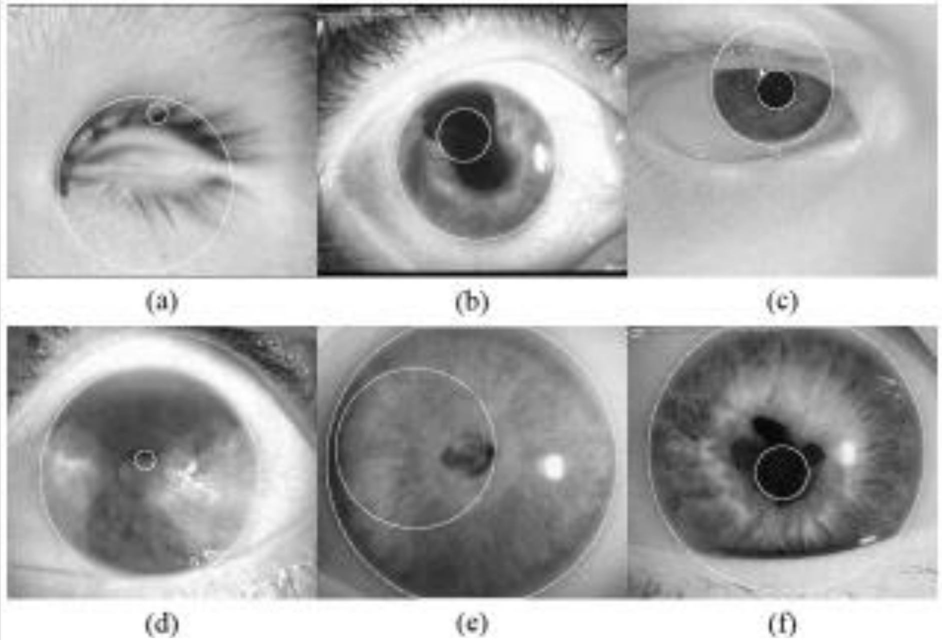
- Dilation is an explanatory variable in regression
- Include two orthogonal terms:
  - Dilation difference D_v
  - Dilation magnitude D_u

MODEL THIS AS A "QUADRATIC BOWL" POLY(D_U,2) + POLY(D_V,2).

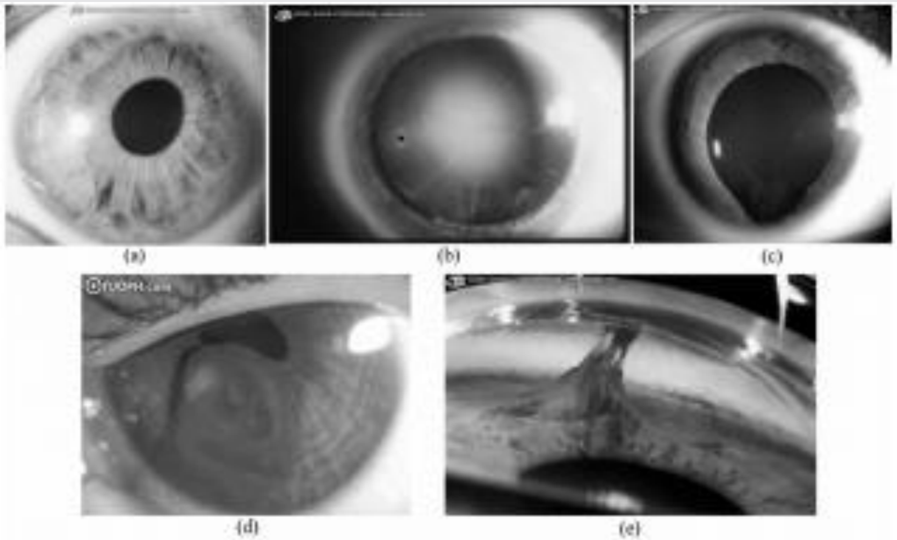
THERE ARE ALTERNATIVES – FUNCTION APPEARS SEPARABLE SO $F(D_1)F(D_2)$

Eye Disorders

- Conditions causing pupil or iris deformation, conditions causing pupil or iris occlusion, and no iris or reduced size are studied
- Database: 111 images from the Atlas of Ophthalmology



Examples from (a) anophthalmia, (b) coloboma, (c) ectropion, (d) synechia, (e) corneal dystrophy, and (f) uveitis.

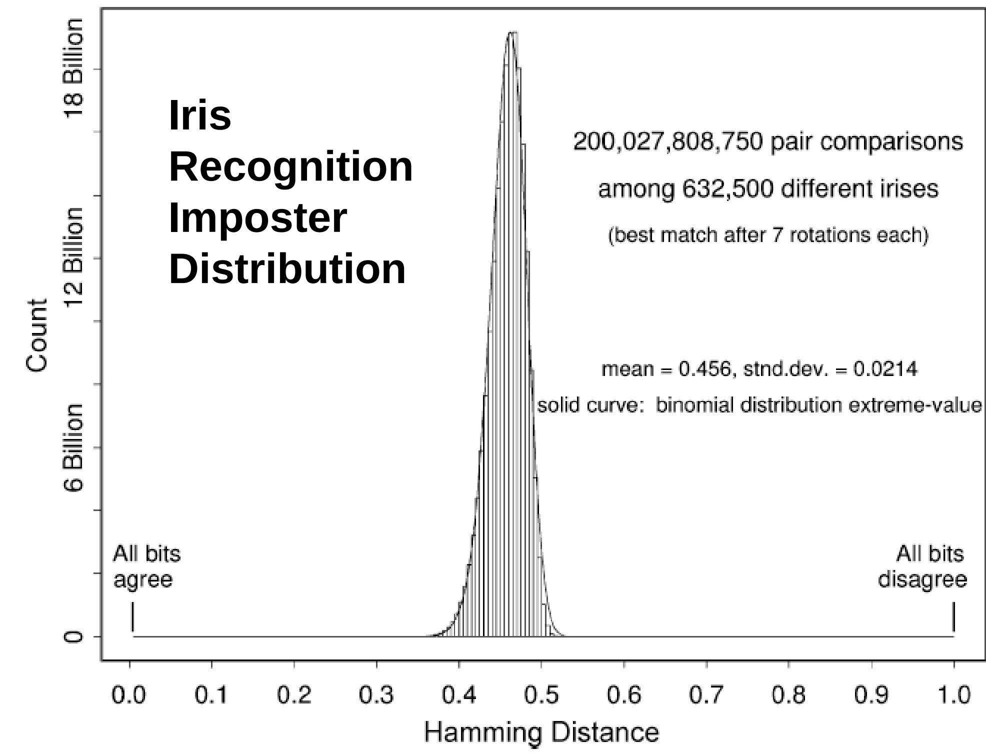


Examples from (a) Axenfeld-Rieger syndrome, (b) cataract, (c) coloboma, (d) epithelial cyst, and (d) synechia

McConnon, George, et al. "Impact of common ophthalmic disorders on iris segmentation." ICB 2012.

Individuality

- Ability to differentiate individuals
- "Individuality", information content, or "capacity"
- Very little published work
- Need large databases which researchers do not typically have access to
- Errors in the "tails"
- UAE 632,500 genuine pairs, > 200B imposter pairs

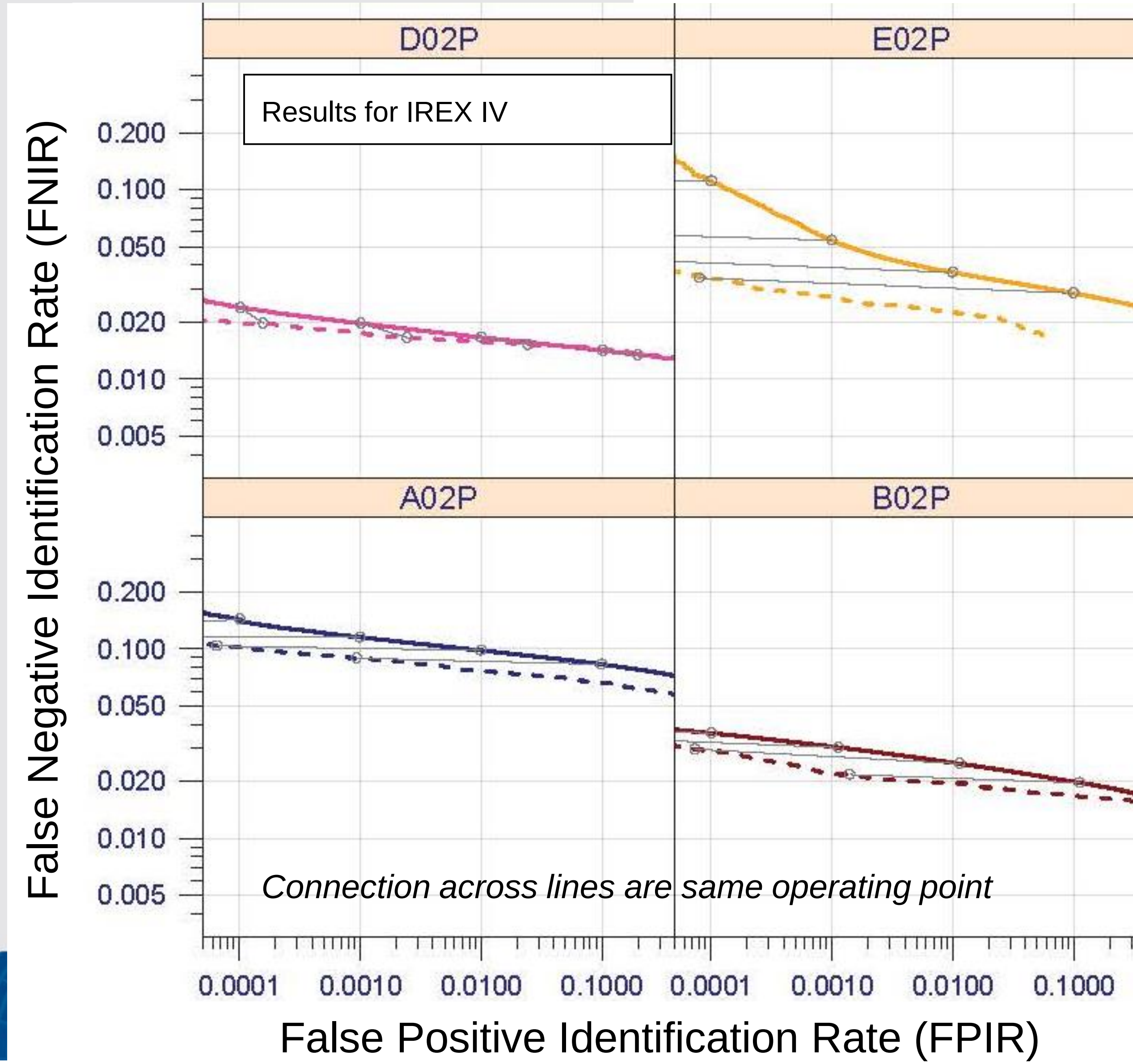


Threshold	False Accept
0.262	1 in 200 billion
0.267	1 in 50 billion
0.272	1 in 13 billion
0.277	1 in 2.7 billion
0.282	1 in 284 million
0.287	1 in 96 million
0.292	1 in 40 million
0.297	1 in 18 million
0.302	1 in 8 million
0.307	1 in 4 million
0.312	1 in 2 million
0.317	1 in 1 million

Daugman J, "Probing the uniqueness and randomness of IrisCodes: Results from 200 billion iris pair comparisons." 2006

Scaling

- Identification performance (1:N) function of database size
- More likely to have a false positive at larger database size

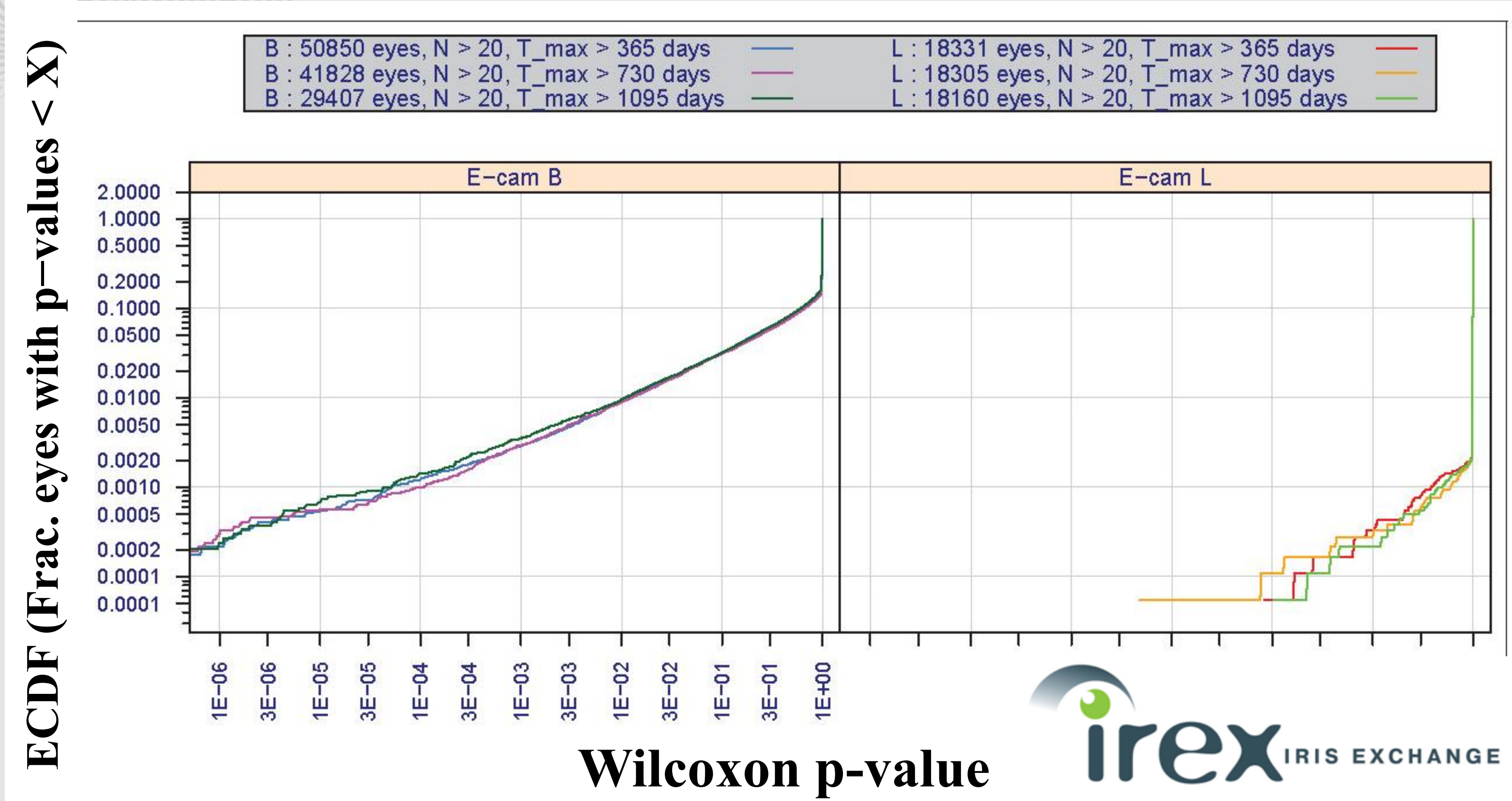


Gallery Database
Dashed: 10,000
Solid: 1.5 M

Quinn, et al, IREX IV, NIST Interagency Report 7949, 2013

Temporal Stability

Permanence—Study of permanence of biometric trait



e.g., 1.1% of eyes give significantly higher late scores vs. early scores for p = 0.01

P. Grother et al, IREX VI Temporal Stability of Iris Recognition Accuracy, NIST Interagency Report 7948, 2013.
S. P. Fenker et al., “Analysis of Template Aging in Iris Biometrics”, 2012.

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Cross Sensor

- Methods to match iris images captured by different sensors [1, 2]
- Notre Dame CSI Database (676 subjects, 264,945 images)
- CASIA CSI Database (350 subjects, 14000 images)
- IIITD Multi-Sensor Iris Database (104 subjects, 832 total images)

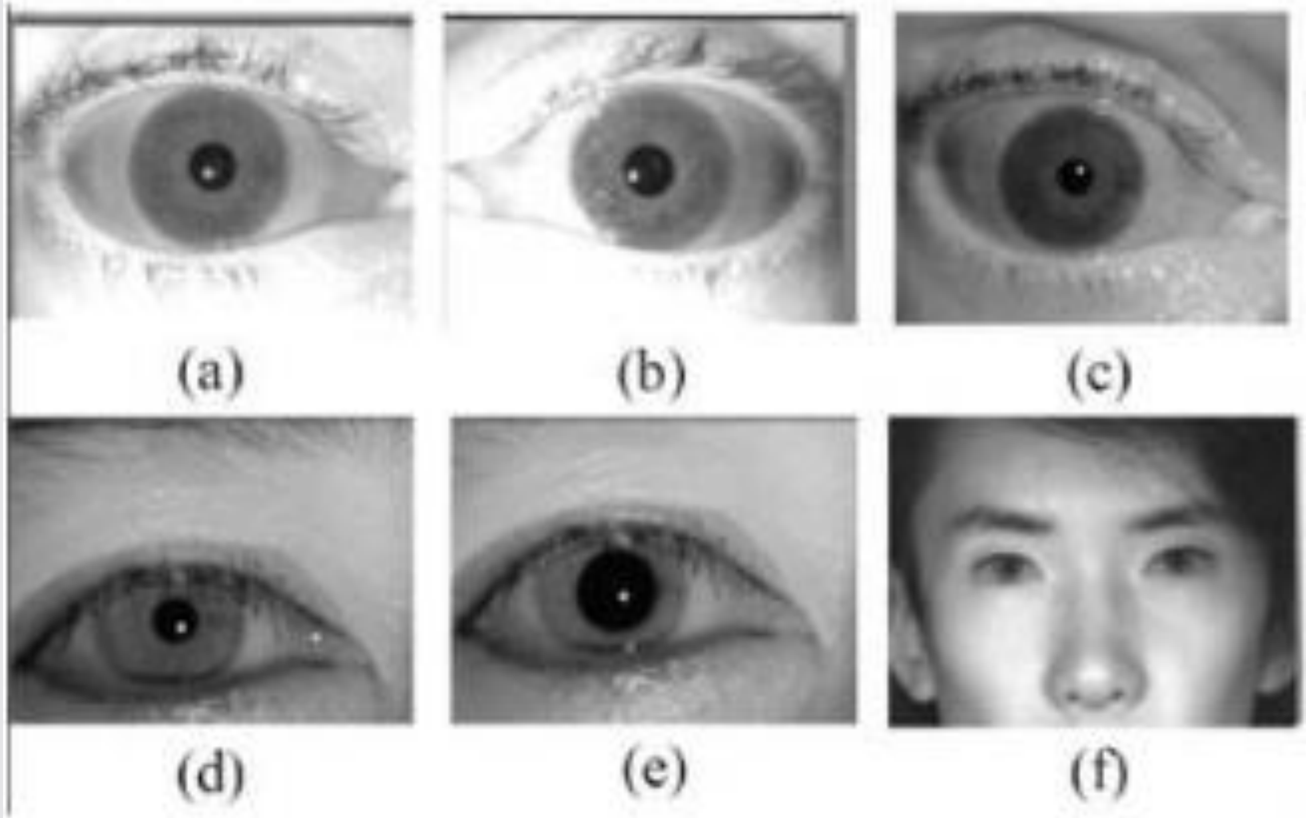


Figure. Iris Images captured by different sensors

[1] Xiao, Lihu, et al. "Coupled feature selection for cross-sensor iris recognition.“ BTAS 2013.
[2] Arora, Sunpreet S., et al. "On iris camera interoperability." BTAS, 2012.

Multi-Spectral

- Iris imaging in multiple spectrums, visible, infrared
- WVU Multi-spectral iris data (35 subjects, 232 images)
- UMKC Visible spectrum, (50 subjects)

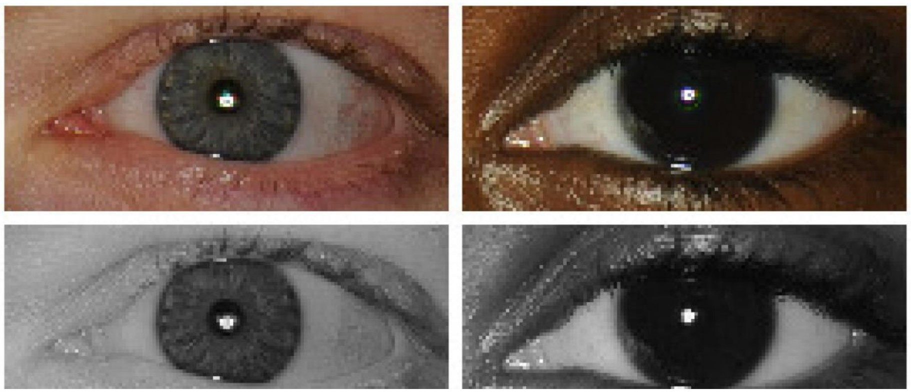


Figure. Visible (top) and red)bottom image for light and dark irises

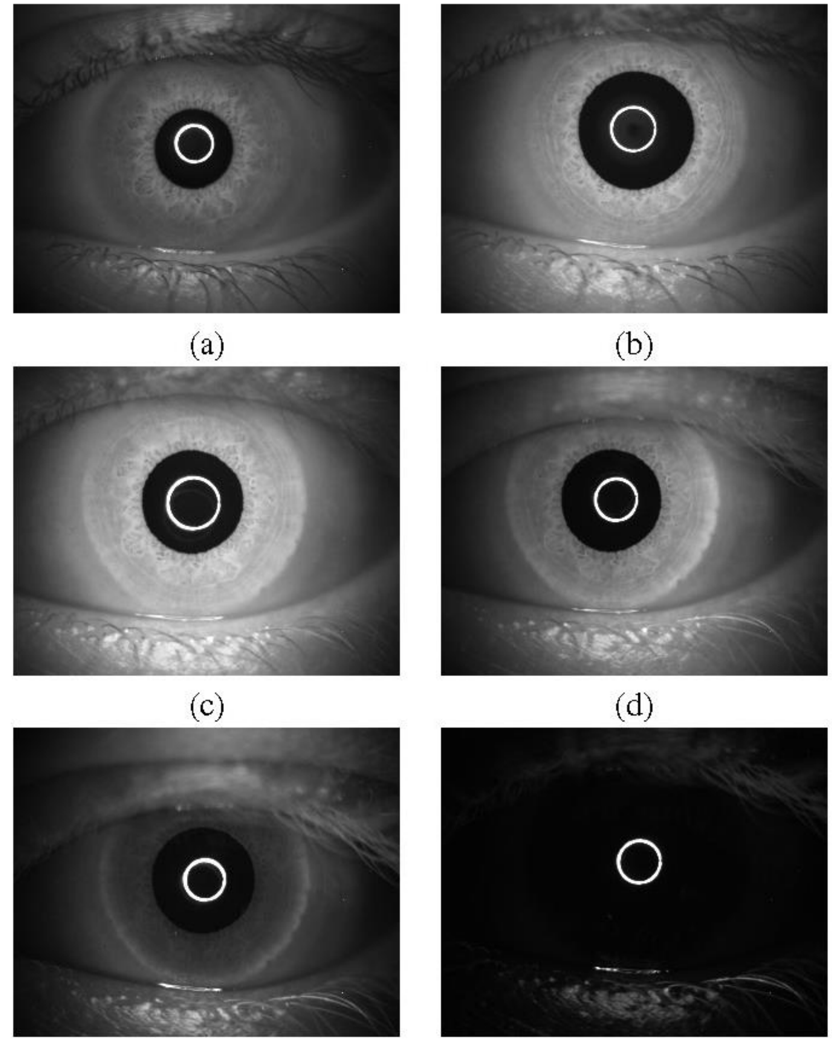
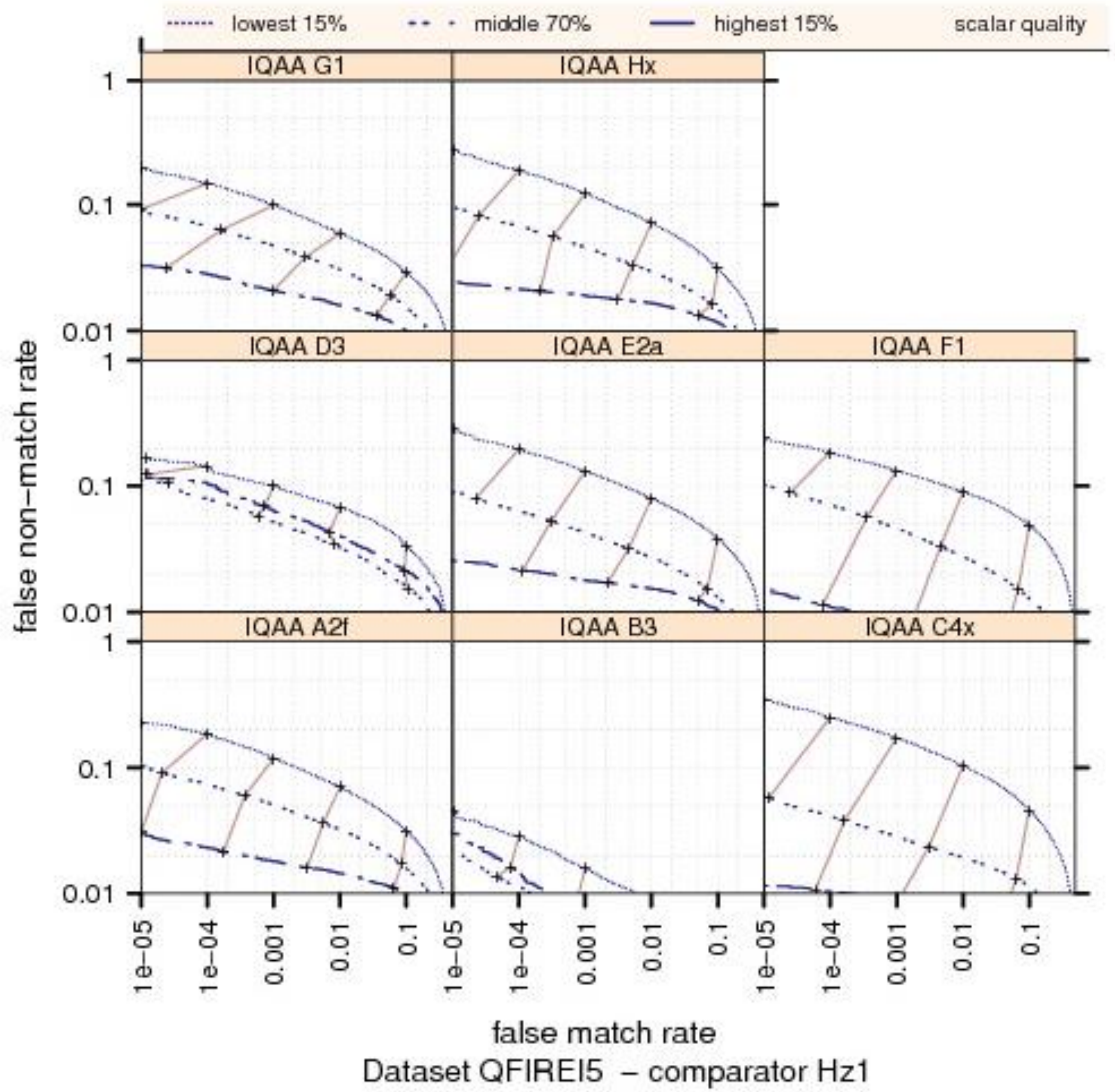


Figure. Sample images obtained at wavelengths (a) 950nm, (b) 1050nm,(c) 1150nm, (d) 1250nm, (e) 1350nm, (f) 1450nm [1]

[1] A. Ross, at al, "Exploring Multispectral Iris Recognition Beyond 900nm," BTAS 2009
[2] V. Gottemukkula, et al, "Fusing Iris and Conjunctival Vasculature: Ocular Biometrics in the Visible Spectrum," HST 2012.
[2] Zuo, J, et al "Cross spectral iris matching based on predictive image mapping." BTAS 2010

Quality

- Reacquisition from a user
- Selection of the best sample
- Preprocessing selection,
- Fusion
- Standardization of quality



Tabassi, E., P. Grother, and W. Salamon. "Irex II-IQCE iris quality calibration and evaluation." Interagency report 7820, 2011.

IREX IRIS EXCHANGE

IDENTIFICATION TECHNOLOGY RESEARCH

Quality

- Iris videos obtained at distances of 5 to 25 feet used to analyze at non-ideal conditions

	Distance (ft)	Description
Iris		
Out-of-focus blur	5, 7, 11, 15, 25	Full range of blur
Illumination	5, 7, 11, 15, 25	Low, Med, High
Angles	5, 7, 11	Straight, Left, Right, Up, Down
Occlusion	5, 7, 11, 15, 25	6 seconds of blinking
Motion blur	7, 15	Slow/Fast Walking
Face		
Out-of-focus blur	5, 15, 25	Full range of blur
Illumination	5, 7, 11, 15, 25	Low, Med, High
Angles	5, 15, 25	Straight, Left, Right, Up, Down
Occlusion	5, 15, 25	Multiple Faces
Motion blur	7, 15	Slow/Fast Walking

Figure. Full database description

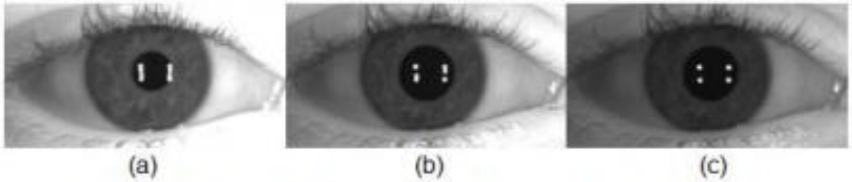


Fig. 6. Example images from iris illumination videos; high contrast (a), medium contrast (b), and low contrast (c)

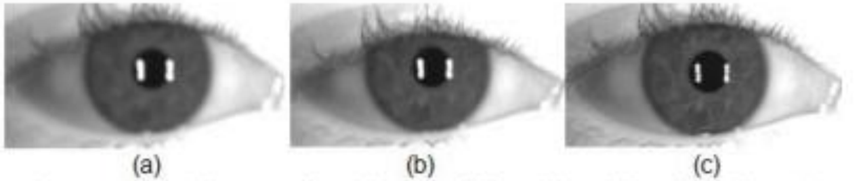


Fig. 7. Example images from iris out-of-focus blur video; high blur (a), medium blur (b), and low blur (c).

Fig. 8. Example images from iris motion blur; slow waling at 7 feet (a), fast walking at 7 feet (b), slow walking at 15 feet (c), fast walking at 15 feet (d).

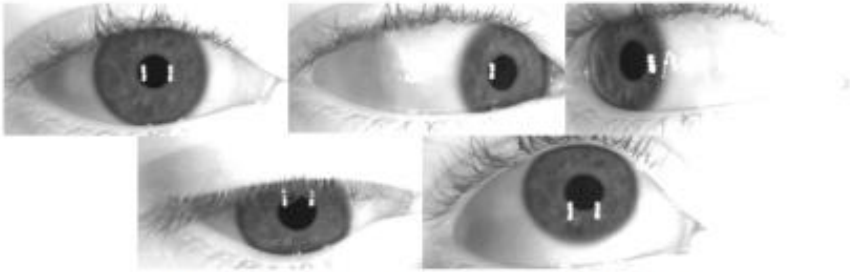


Fig. 9. Example images from iris angle video.

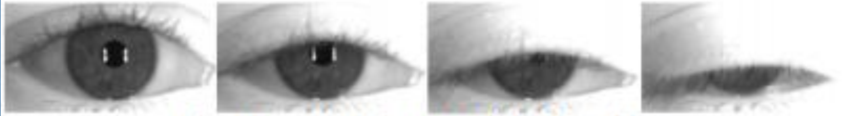


Fig. 10. Example images of blinking video.

[1] Johnson, P. A., et al. "Quality in face and iris research ensemble (Q-FIRE)." BTAS 2010.

Quality

- Iris segmentation performance is impacted by image quality
- Sharpness (defocus blur), motion blur and interlace, contrast of iris boundaries, circularity of iris boundaries, gray scale spread, and usable boundary
- Database: BioSec (3200 iris images, 200 individuals)

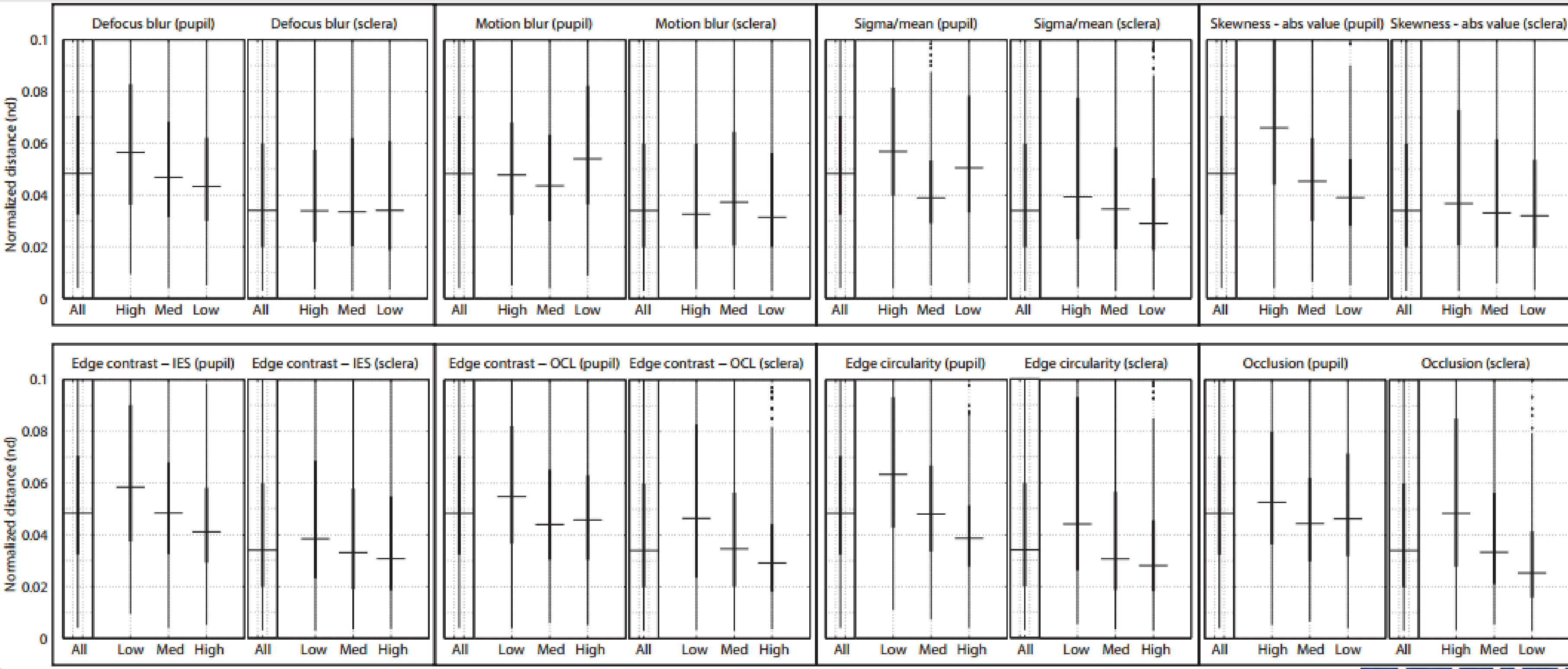


Figure. Performance of segmentation based on different quality measures

Alonso-Fernandez and Bigun. "Quality factors affecting iris segmentation and matching." ICB 2013.

Distance

- Iris images acquired under less constraints has noise highly correlated with the bit consistency [1]
- Computationally efficient iris segmentation approach for at-a-distance and less constrained images [2]
- Databases: CASIA V4-distance (131 subjects, 935 images), UBIRIS V2 (151 subjects, 864 images)

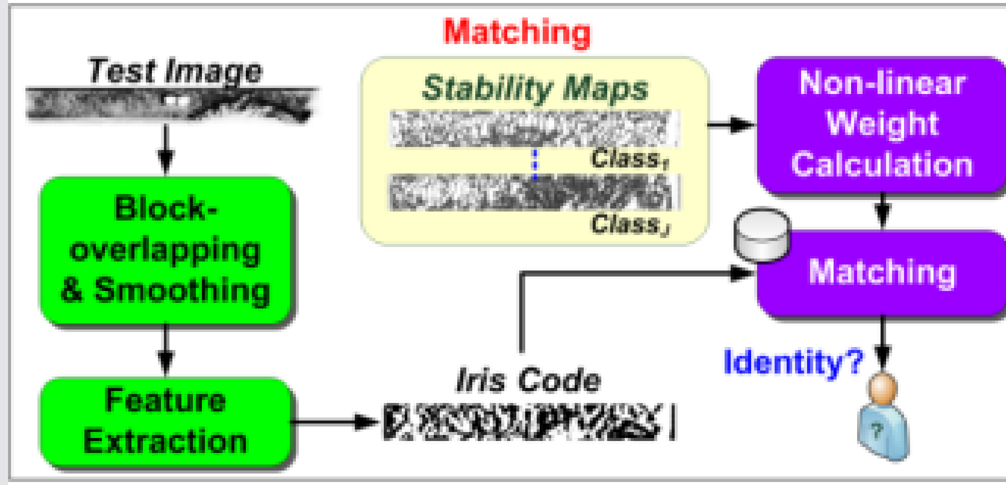


Figure. Block diagram of the developed iris recognition scheme. (a) Stability maps learning phase, (b) Matching phase.

(a) (b)

Figure. Initial assignment of labels. (a) Input image, (b) Assigned labels (Cyan - foreground; Gray – background; Black - otherwise).

[1] Tan, CW, and Kumar A. "Adaptive and localized iris weight map for accurate iris recognition under less constrained environments." BTAS 2013.
[2] Tan, CW, and Kumar. "Efficient iris segmentation using Grow-Cut algorithm for remotely acquired iris images.“ BTAS 2012.

Distance

Venugopalan, Shreyas, et al. "Long range iris acquisition system for stationary and mobile subjects." IJCB 2011.

- Ongoing work in designing, developing system with less cooperative acquisition (less constraint)
- Capture images of iris up to 8 meters away, 200 pixel resolution across diameter
- Capture distance of 12 meters with 150 pixel resolution
- Velocity estimation, focus tracking modules: acquisition of moving subjects

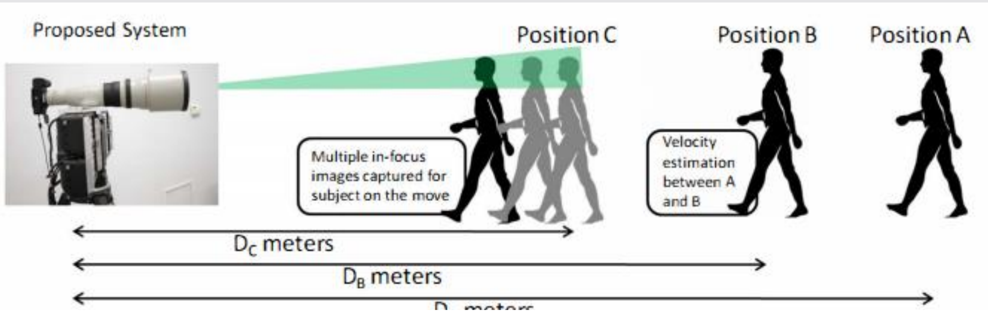


Figure. Subject approaches the system, crosses variable checkpoints A and B, estimates his/her speed. Focus position is then set to a position C to obtain an iris of required resolution . A number of in-focus images are then acquired by changing the focus continuously based on subject distances estimated.

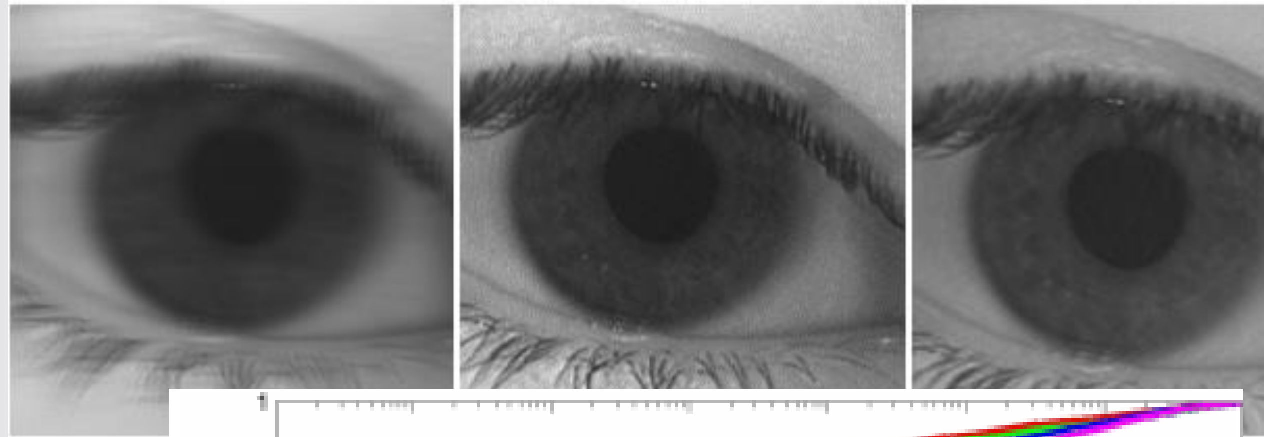
(a)

(b)

Figure. (a) shows an iris image capture from a subject standing still at a distance of 6 meters from system (b) shows an image from the same subject at 7 meters. Both cropped from face images.

On the Move

- Fluttering shutter: camera's shutter flutters between open/close while exposure is accumulated on the sensor
- High quality image can be recovered with low noise levels with blur estimation and de-blurring
- Dataset: Synthetic experiments using NIST ICE dataset, real experiments using 600 collected flutter shutter images



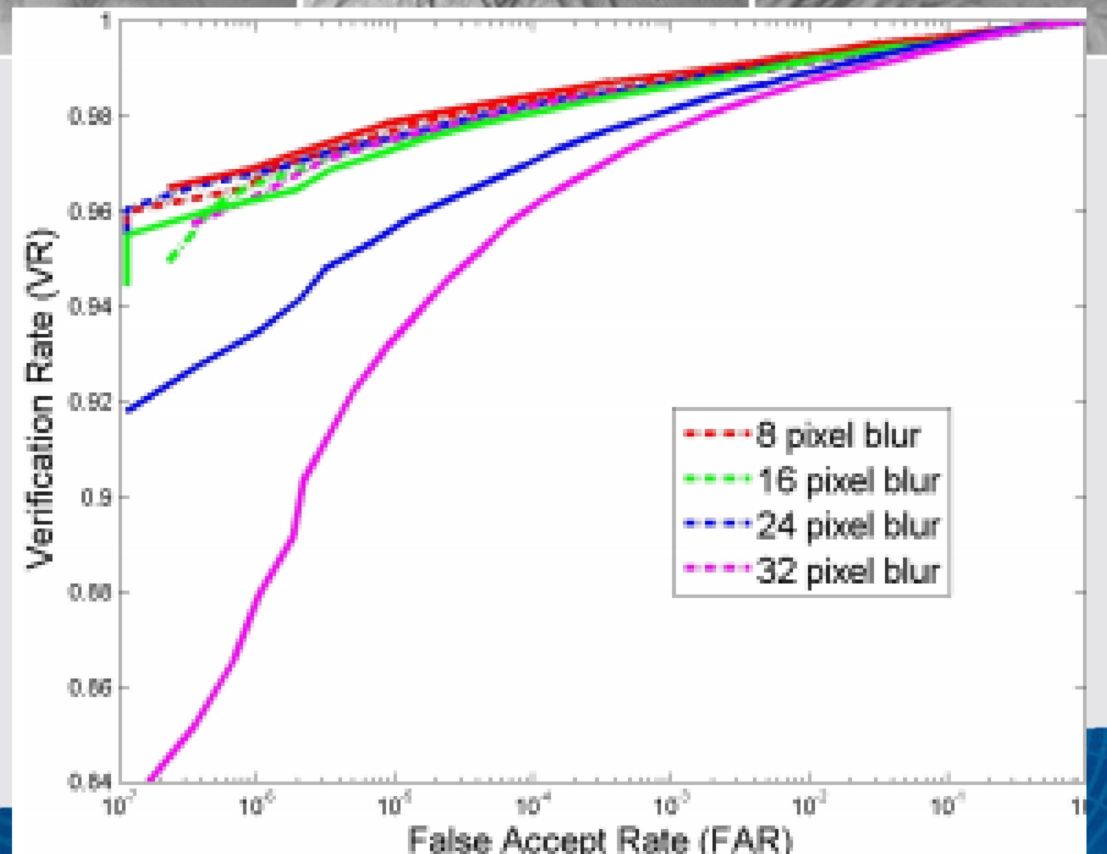


Figure. ROC curves for synthetically de-blurred images from the ICE dataset, using a traditional shutter (solid lines) and a flutter shutter (dashed lines)

McCloskey, S, Wing S, and JJelinek. "Iris capture from moving subjects using a fluttering shutter." BTAS 2010.

Iris-on-the-Move (IOM) Iris recognition systems

Example: UNI-Cam: Unconstrained Iris Camera

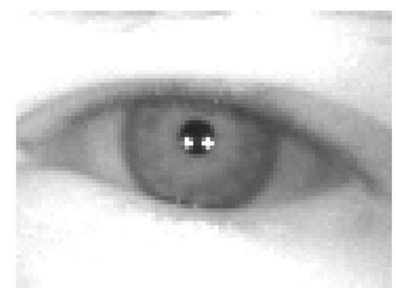
- Match off-axis (pose and gaze) iris images
- Distance range 1 to ~ 2m
- Approach speed up to 1m/s
- Diverse ambient lighting conditions

Fast iris capture of approaching subjects at an angle up to 40°.

Off-axis, on- the-move, iris matching in unstructured, realistic surroundings

Dataset needs: off-axis imagery, low resolution data, variable pupil contrast

Oblique gaze, sun on face



Low resolution: 30 pix/cm

Mobile

DELTA ID

eyeLock®

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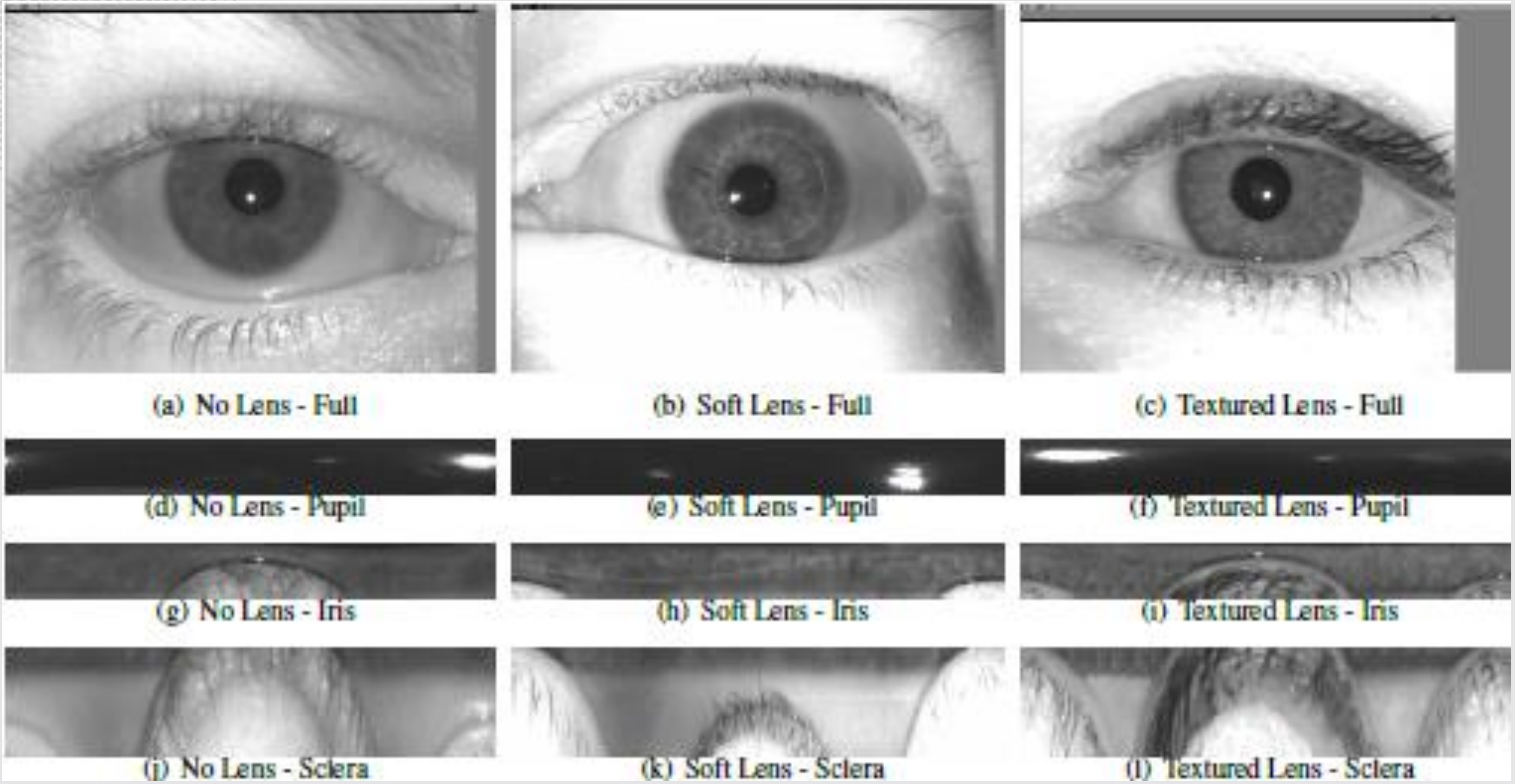
Contact Lenses

Doyle, J et al. "Automated classification of contact lens type in iris images."ICB 2013.



- Discrimination between wearing no lens, wearing clear prescription lens, wearing textured cosmetic lens
- Notre Dame Cosmetic Contact Lenses 2012 dataset, 3000 training images, 1200 verification images, LG 4000 iris camera

Contact Lenses

- Challenge of patterned contact lenses: variety of textures from many manufacturers
- Method: Lens detection, reject cases with obfuscated patterns
- Existing lens detection algorithms improve performance: edge sharpness, textural features, GLCM features, LBP and SVM based
- IIIT-D Contact Lens Iris Database, 6570 images from 101 subjects; no lens, soft lens, colored lens

	Normal	Colored	Transparent	Total
Normal	192	215	179	586
Colored	205	274	124	603
Transparent	197	179	188	564
Total	594	668	491	1753

Table 7. Confusion matrix for lens detection using the GLCM features [7].

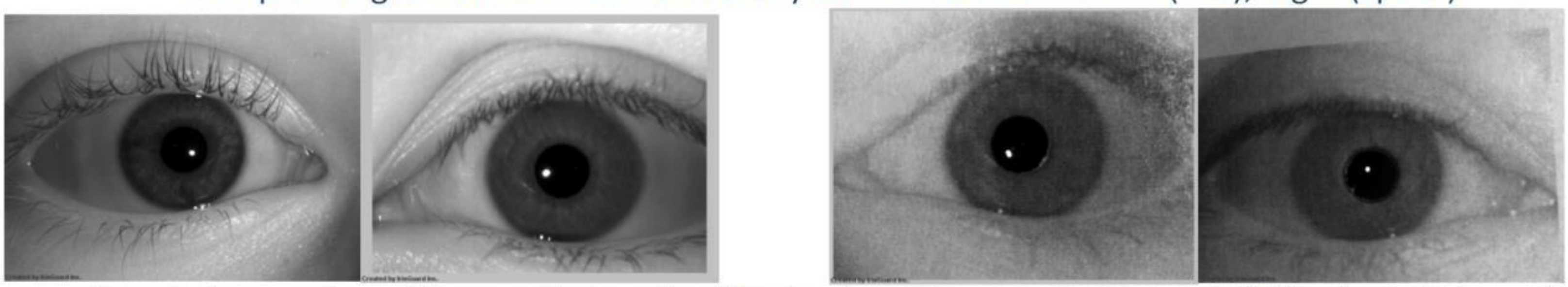
	Normal	Colored	Transparent	Total
Normal	384	37	165	586
Colored	30	539	34	603
Transparent	297	26	241	564
Total	711	602	440	1753

Table 8. Confusion matrix for lens detection using LBP features and SVM.

Kohli, Naman, et al. "Revisiting iris recognition with color cosmetic contact lenses." Biometrics (ICB), 2013 International Conference on. IEEE, 2013.

Examples from Iris LivDet Database

Sample Images from Clarkson University Liveness Database: left (live), right (spoof)

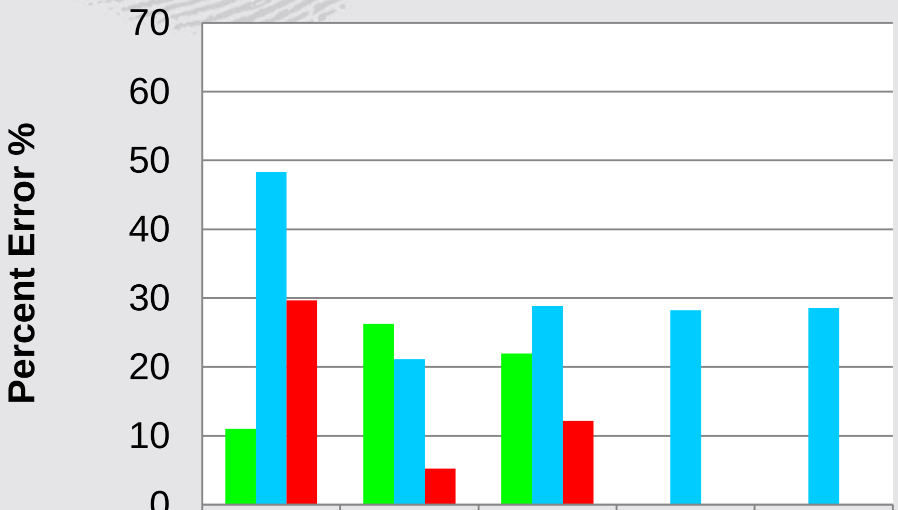


Sample Images from Warsaw University of Technology Liveness Database: left (live), right (spoof)

Sample Images from Notre Dame University Liveness Database: left (live), right (spoof)

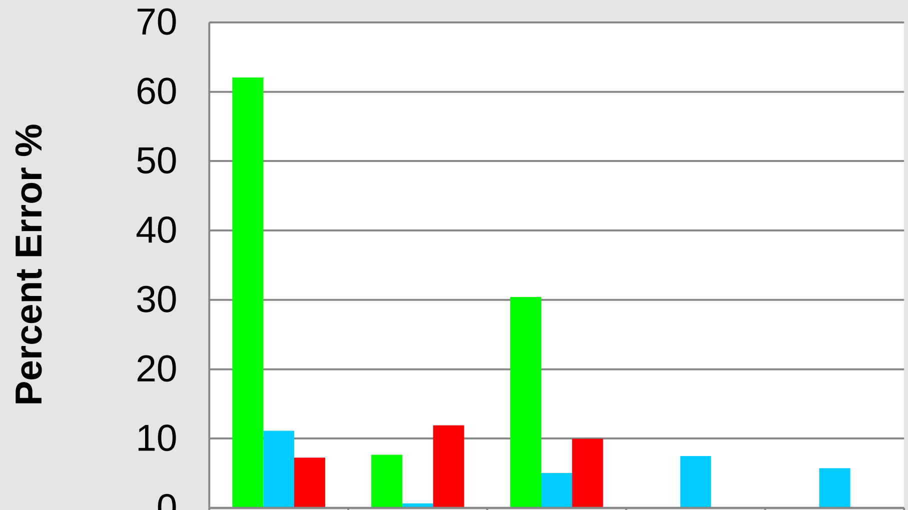
Results-LivDet 2013 Iris

Rate of misclassified Live Iris Images (ferrlive) for submitted algorithms



	Clarkson	Warsaw	2 Dataset Avg	Notre	3 Dataset Avg
ATVS	10.99	26.28	21.95		
Federico	48.37	21.15	28.85	28.25	28.56
Porto	29.67	5.23	12.18		

Rate of misclassified Spoof Iris Images (ferrfake) for submitted algorithms



	Clarkson	Warsaw	2 Dataset Avg	Notre	3 Dataset Avg
ATVS	62.05	7.68	30.42		
Federico	11.14	0.65	5.04	7.5	5.716
Porto	7.27	11.93	9.98		

D Yambay, et al, LivDet-Iris 2013 – Iris Liveness Detection Competition 2013, IJCB 2014

Liveness

- Iris liveness detection scheme based on quality related measures
- Based on focus, motion, occlusion, contract, pupil dilation
- Database has 50 users of BioSec baseline, 800 printed iris images and its original samples

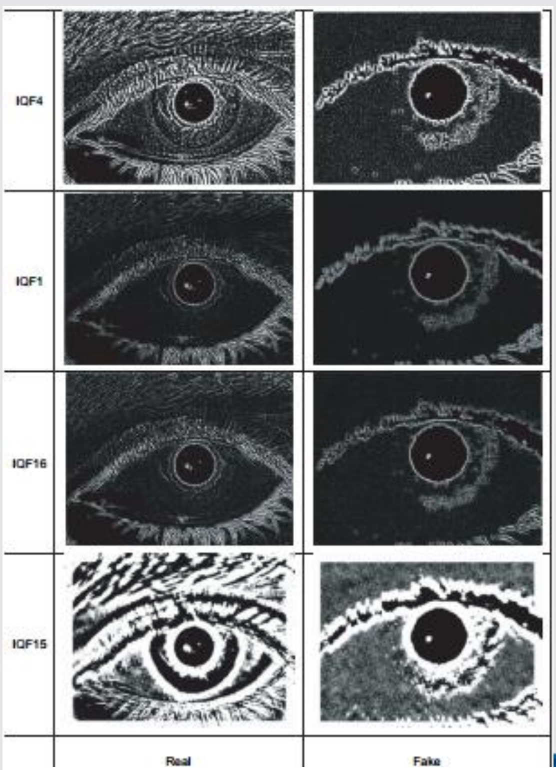


Figure. Examples of different focus quality features for real and fake irises

Figure. Power spectrum of a real and a fake iris on its primary direction

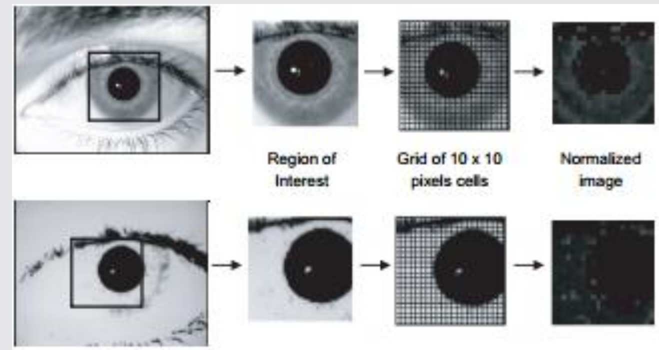


Figure. Process to calculate local contrast

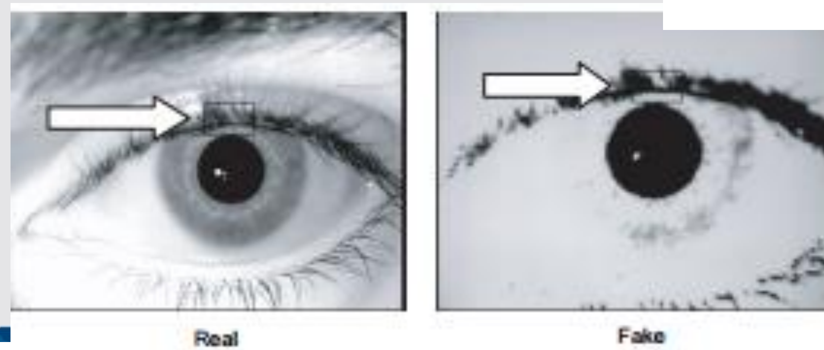


Figure. ROI used to estimate the iris occlusion

Galbally, J, et al. "Iris liveness detection based on quality related features." ICB 2012.

Outline

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  - Modeling
  - Dilation
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  - Cross sensor
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- Beyond Iris
  - Ocular
  - Vascular
  - Eye Movement
- Database Sharing

Beyond Iris

Ocular

- Ocular are used instead of or in addition to iris images [1, 2, 3]
- FOCS (face and ocular challenge set), 9588 images of 126 subjects

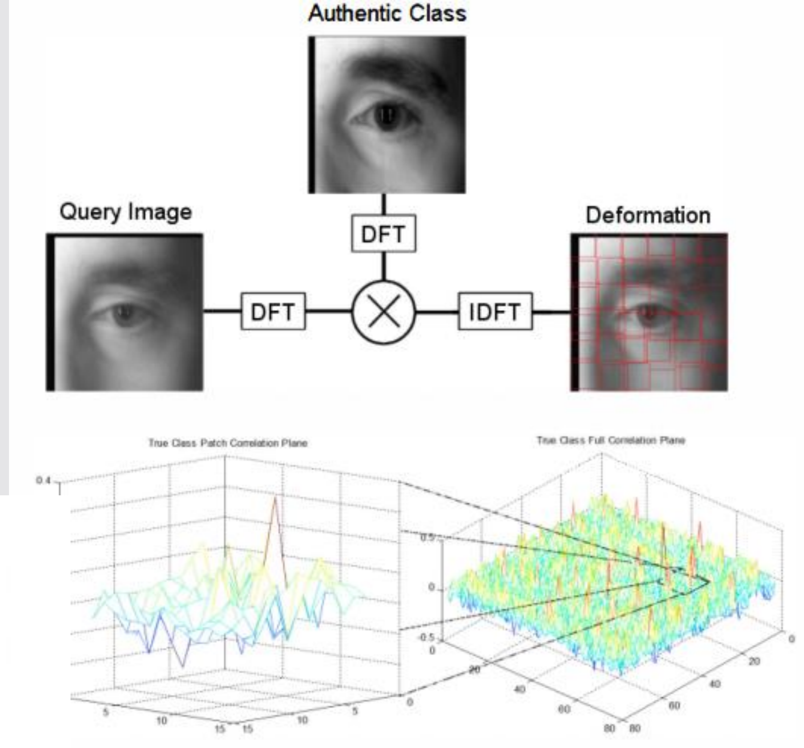

Figure. True class deformation when correlating an authentic class query image [1]

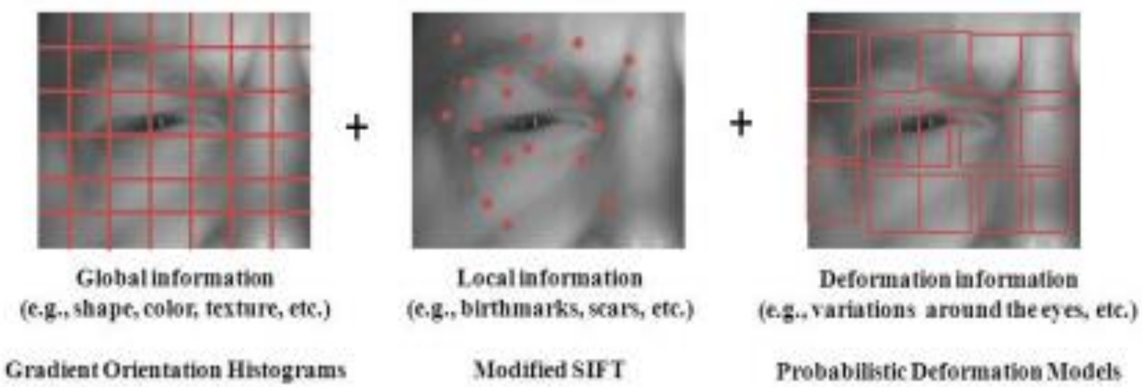

Figure. The three processing methods for non-ideal ocular images [3]

[1] Boddeti, V et al. "A comparative evaluation of iris and ocular recognition methods on challenging ocular images."IJCB 2011.
[2] Padole, C., et al. "Periocular recognition: Analysis of performance degradation factors." ICB, 2012.
[3] Ross, A, et al. "Matching highly non-ideal ocular images: An information fusion approach." ICB 2012.

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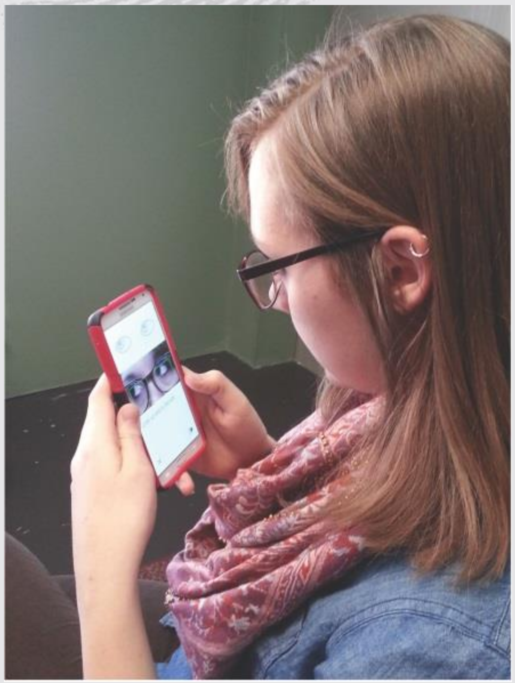
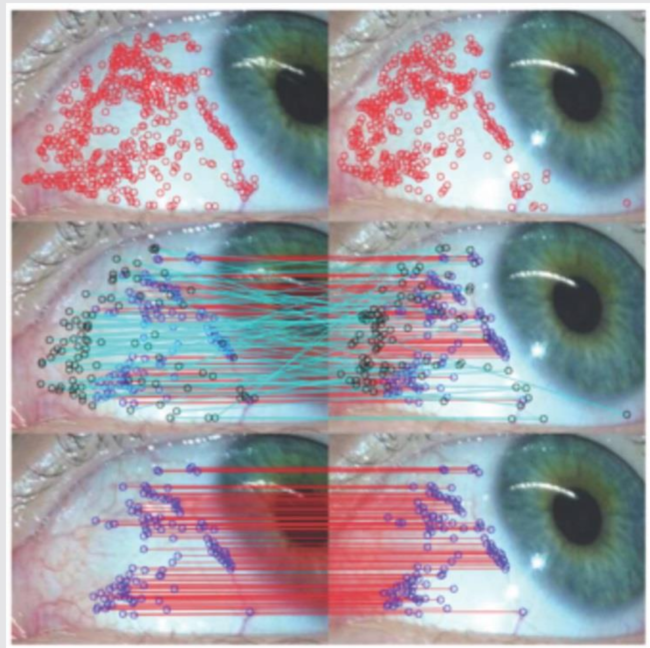
Clarkson University defy convention | West Virginia University | The University of Arizona | University at Buffalo The State University of New York

Beyond Iris

Conjunctival Vasculature





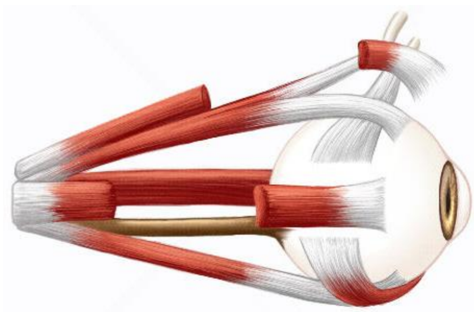
EYEVERIFY

Gottemukkula V, et al "Fusing Iris and Conjunctival Vasculature: Ocular Biometrics in the Visible Spectrum," IEEE International Homeland Security Technologies Conference, 2012

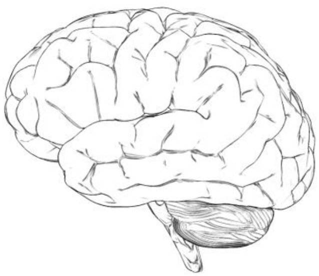
Beyond Iris

Eye Movements

Oculomotor Plant



Brain



Ocular Biometrics

Iris

Benefits:

Enhanced counterfeit resistance

Improved accuracy when iris accuracy is low

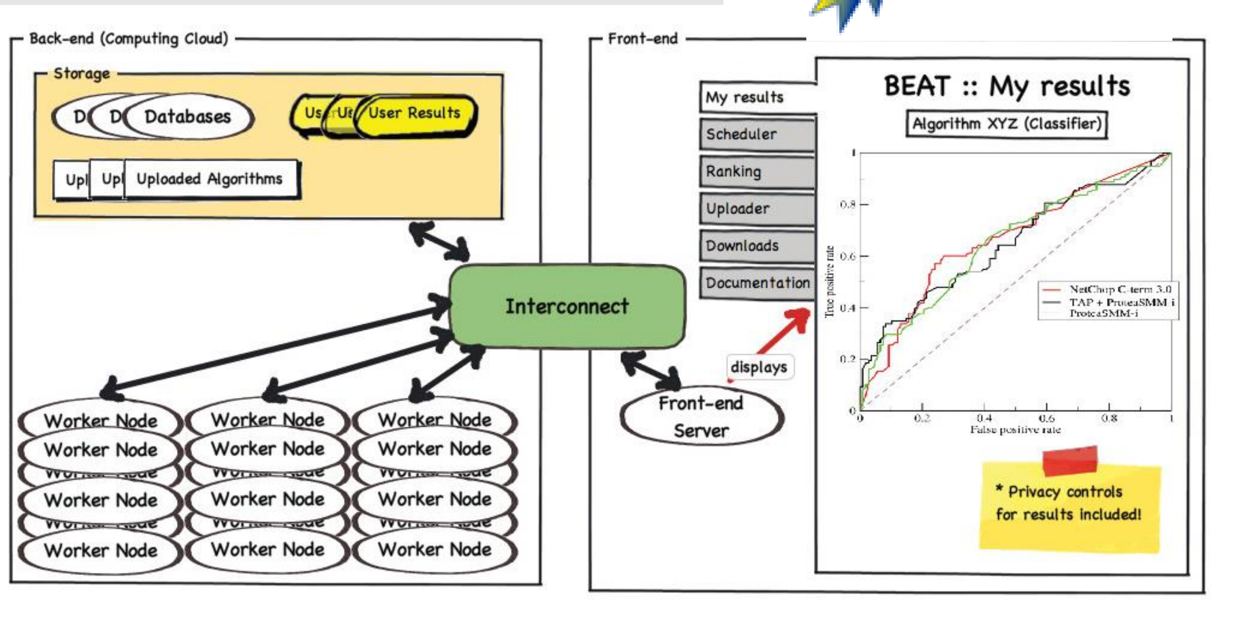
Detection of person's states, e.g., fatigue, concussions, intoxication.

Same hardware as iris recognition

O. V. Komogortsev et al Biometric Authentication via Complex Oculomotor Behavior, BTAS, 2013.

Database Sharing

- Need frameworks for data sharing where biometric data is not revealed
- Algorithms are uploaded to data; common protocol, common data, reproducible research



Fingerprint Verification Competition Ongoing, https://biolab.csr.unibo.it/fvcongoing
Anjos, et al, Reproducible Biometrics Evaluation and Testing with the BEAT Platform, IBPC 2013

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Thank you!