Iris Multibiometrics

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PROFESSOR

Outline

- Multibiometrics: terminology
- Iris color and multispectral iris biometrics
- Iris + X multibiometrics
- Bonus!

Multibiometrics

- "More than one" of "something" used in identity decision (<u>fused</u>)
- Multi-site: eye + face, gait + palm, …
- Multi-spectral: visible + thermal, multiple visible color bands, …
- Multi-algorithm (applied to same signature)
- Or combinations of these

Multibiometric fusion

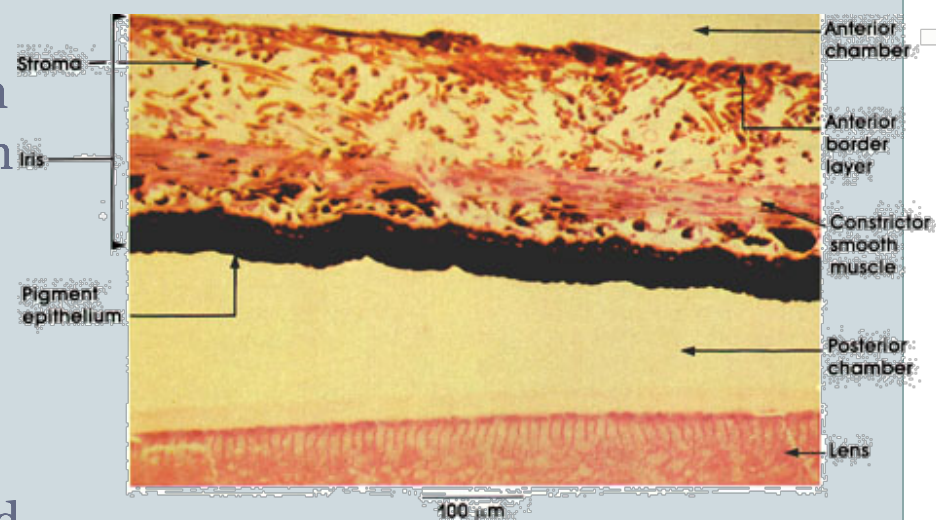
- Image (or signal) level: concatenation, averaging, etc.
- Feature level
- Score level
- Rank level
- Decision level

Multi-spectral iris recognition

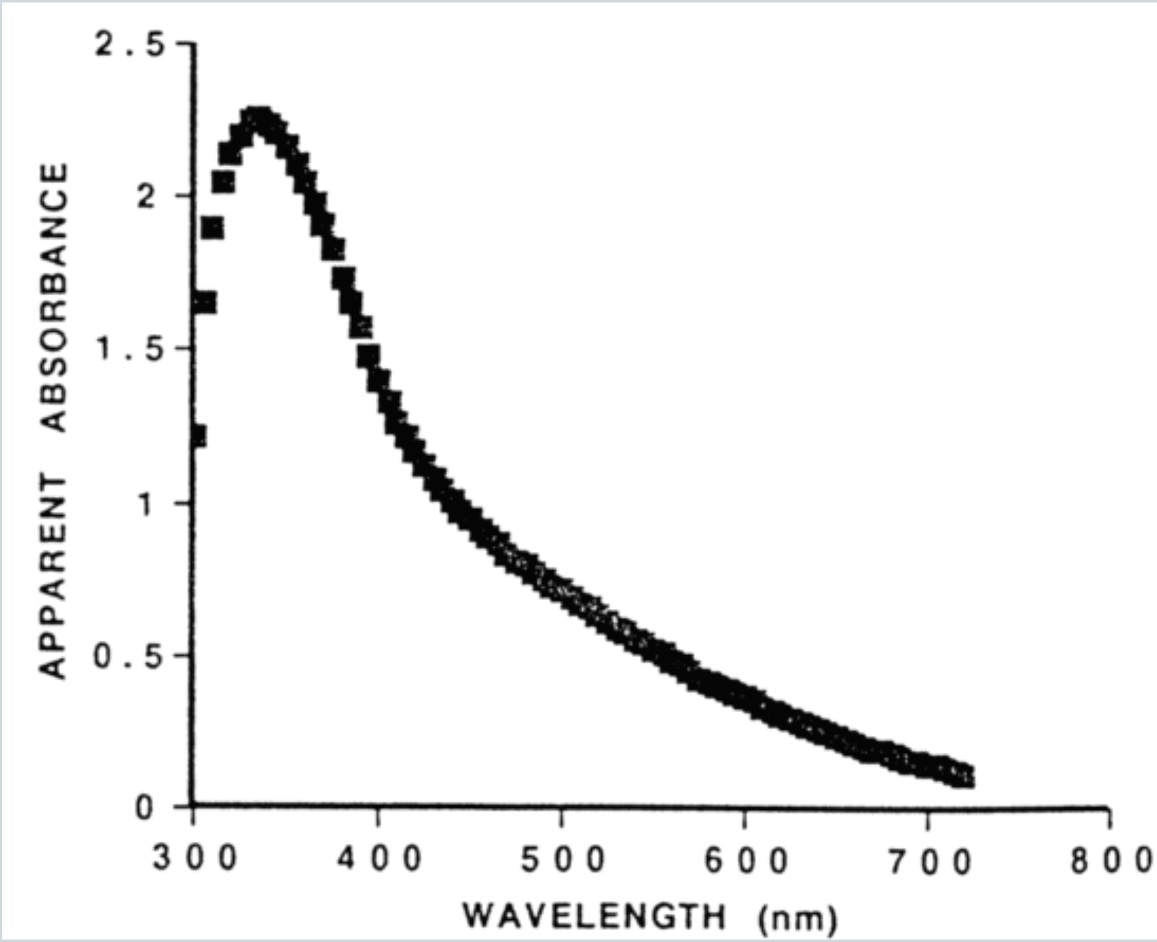
- Idea: process images of the iris captured at multiple wavelengths (using Daugman's method, or some other technique)
- Motivations
  - iris texture appearance varies by wavelength
  - Eye color influences highest contrast appearance
  - Free (most sensors capture all wavelengths between near-UV and near-IR)

Eye color redux

- Iris
  - Anterior border layer
    - Pigment cells, collagen fibers, fibroblasts
  - Stromal layer
    - Like ABL, but less dense: “loosely arranged collagen fibrils”.
  - Iris Pigment Epithelium
    - Pigmentation not effected strongly by eye color
- Melanin
  - Eumelanin: brown-black melanin
  - Pheomelanin: yellow-red melanin
  - Dark eyes: lots of both
  - Blue eyes: little of either
- However, eye color not completely governed by melanin content
  - Other pigments: hemoglobins and carotenoids (lutein, zeaxanthin)
  - Rayleigh scattering



Absorption spectrum of melanin



John Daugman, http://www.cl.cam.ac.uk/~jgd1000/melanin.html

Synthetic melanin responses

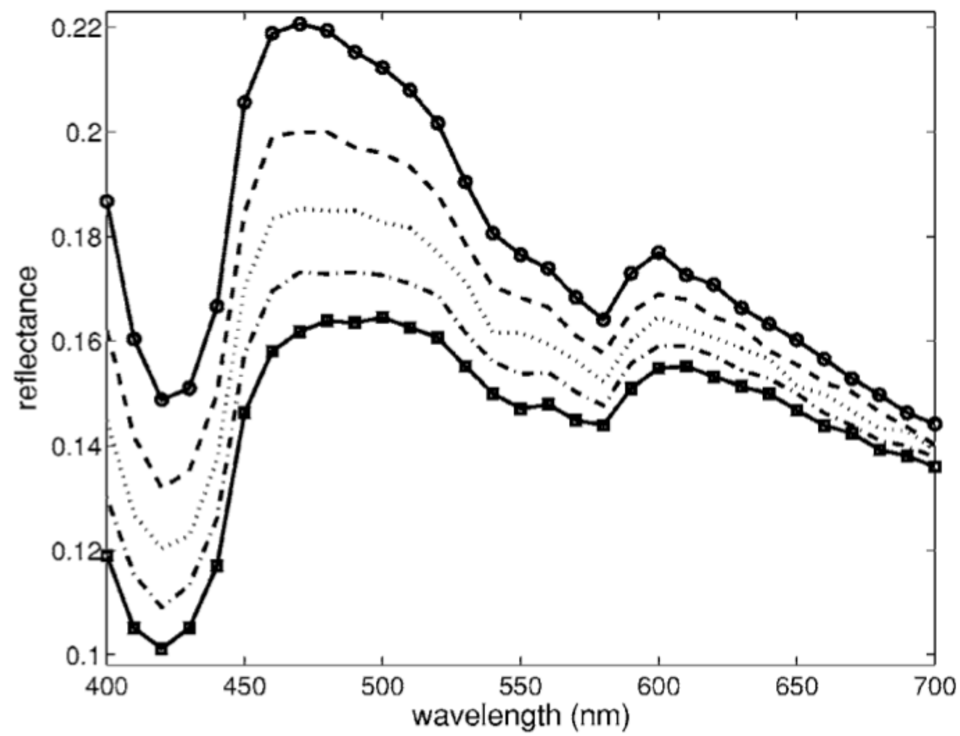


Fig. 1 Changes in the spectral signature of a simulated lightly pigmented iris in response to different PMSL values: 10% (squares), 30% (dashed-dotted line), 50% (dotted line), 70% (dashed line), and 90% (circles).

Specifying iris color

Heterochromia: different iris colors

- Central
- Iridal
  - Dan Aykroyd, Jane Seymour
  - NOT David Bowie

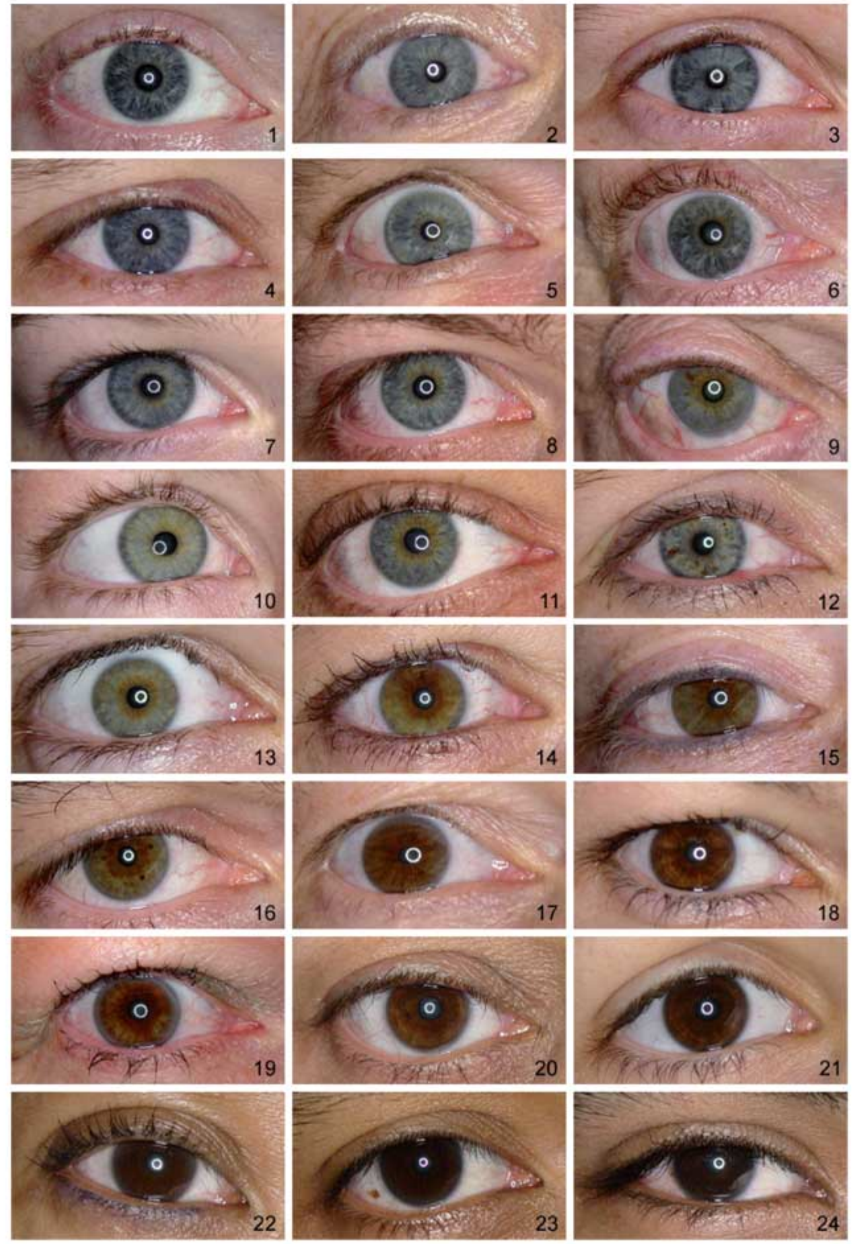


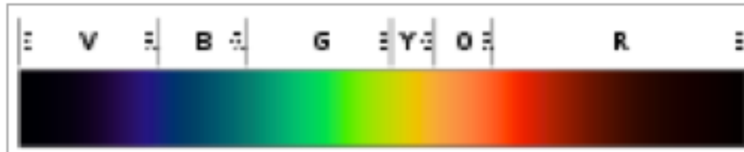
FIGURE 3
Reference set for classification of iris pigmentation, in order from least (number 1) to most (number 24) iris pigmentation. The presented order is based on ranking by 4 observers. For practical use, this figure can be obtained from the authors upon request.

Multispectral Iris imaging

- Multispectral: multiple “colors”
- Take more than one image of the eye simultaneously
  - Easy! Color cameras do this all the time…
- Design parameters
  - How many images?
  - What colors?
  - How “broad” (in wavelength) is a color?

Spectral decomposition

- Visible spectrum: 380-750nm (3800-7500 Å)
- Continuous (no hard boundaries)
- Ocular tricks (metamerism)



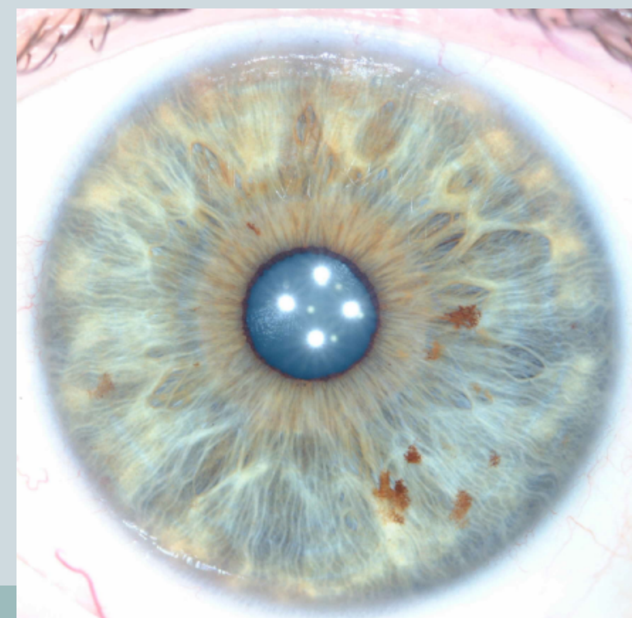
Color	Frequency	Wavelength
violet	668–789 THz	380–450 nm
blue	631–668 THz	450–475 nm
cyan	606–630 THz	476–495 nm
green	526–606 THz	495–570 nm
yellow	508–526 THz	570–590 nm
orange	484–508 THz	590–620 nm
red	400–484 THz	620–750 nm

Easiest multispectral iris capture

Good old RGB

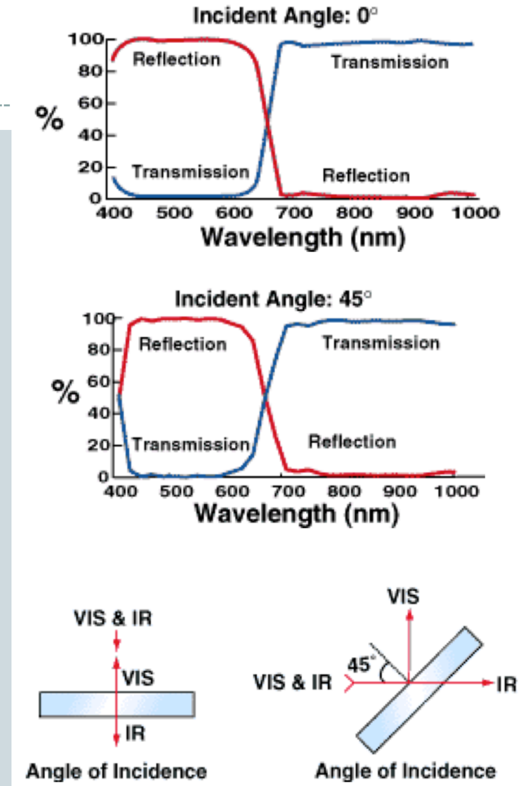
- UBIRIS image (H. Proença) ➔
  (100 pix pupil diam)

- Miles Labs image ➔
  (1600 pix (!) pupil diam)

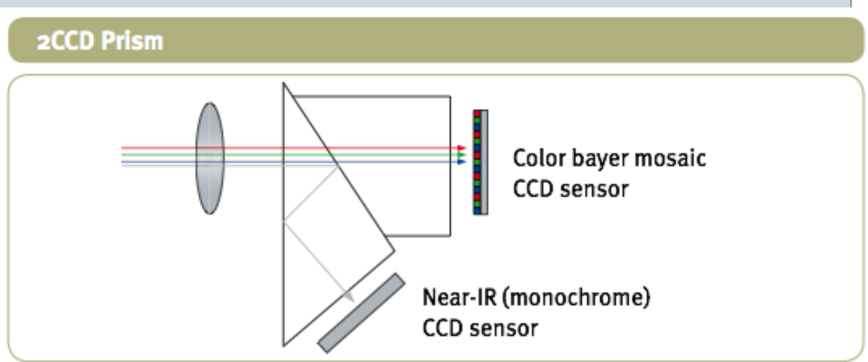


Slightly harder but still pretty easy multispectral iris capture

- Visible + **NIR** (4 images)
- Two hardware methods
  - Use a NIR-sensitive CCD array; block visible light using a movable "cold mirror"
  - Split the incoming light into 2 streams and sense them with registered arrays (JAI AD-080)



Source: Edmund Optics



Patent App: Visible + NIR

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Burge et al.

(10) **Pub. No.: US 2009/0279790 A1**

(43) **Pub. Date: Nov. 12, 2009**

(54) **MULTISPECTRAL IRIS FUSION FOR ENHANCEMENT AND INTEROPERABILITY**

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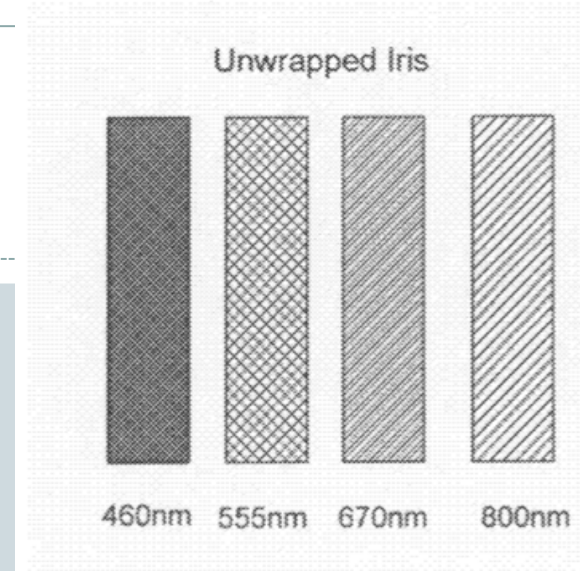
(57) **ABSTRACT**

A multispectral iris recognition system includes a multispectral camera adapted to acquire spatially registered iris images simultaneously in at least three wavelengths and a database adapted to store the acquired iris images. A texture analysis section identifies an area within each acquired iris image having a maximum texture at each of the wavelengths. The identified areas are combined to generate an enhanced iris image. Additionally, a visible light iris image is acquired and stored along with a set of transformation mappings in a database. The acquired visible light iris image is modeled in a texture model, which clusters textures from the acquired visible light iris image. A mapping is selected from the database for each of the clusters. The selected mappings are applied to the acquired visible light iris image to generate a Near-Infrared equivalent.

Patent App elements

- Color + NIR
- Representative image generation (clustering?)



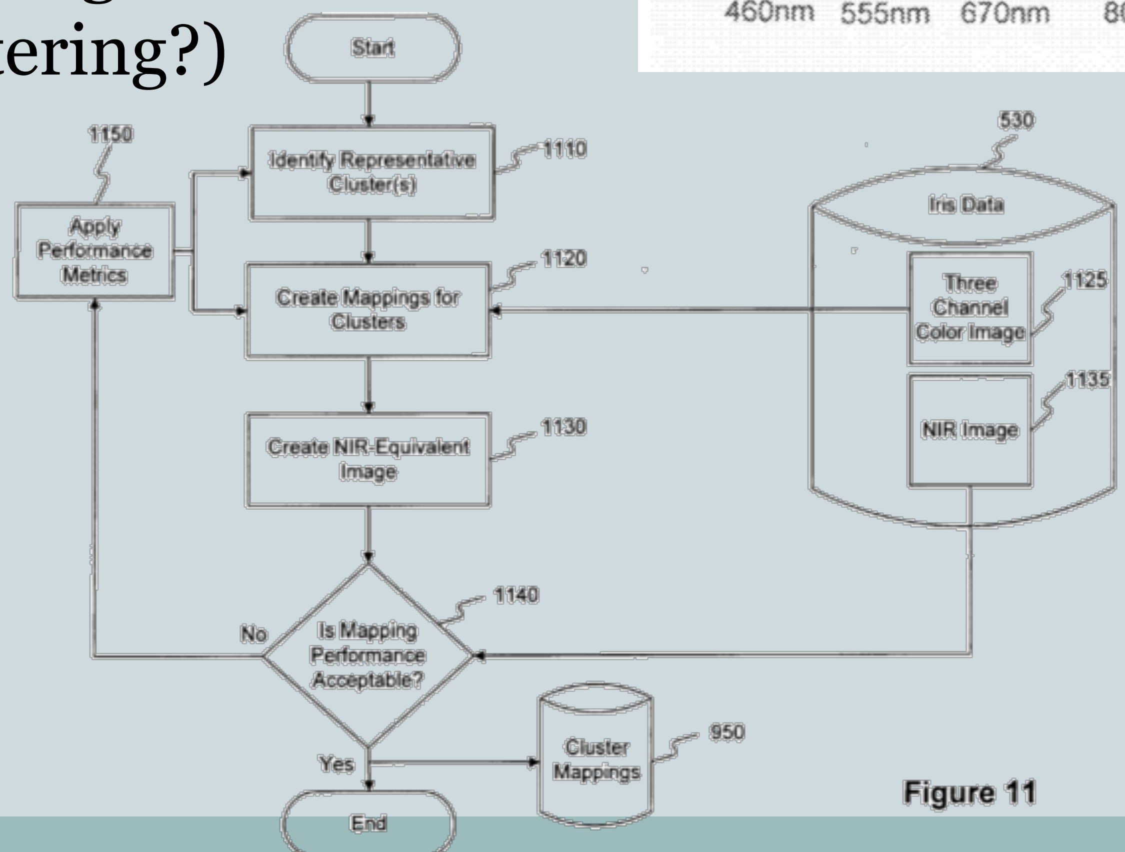


Figure 11

Claims

What is claimed is:

1. A multispectral iris recognition system comprising:

a multispectral imaging device adapted to acquire spatially registered images of an iris simultaneously in at least three wavelengths;

a database adapted to store the acquired images;

a texture analysis section adapted to identify an area within each acquired image having a maximum texture at each of the wavelengths; and

an image generation section adapted to combine the identified areas to generate an enhanced image of the iris.

2. The system of claim 1, wherein the image generation section is further adapted to combine the identified areas at a pixel level.

3. The system of claim 1, wherein the multispectral acquisition device includes a single lens camera and a broadband LED-ring light.

4. The system of claim 1, further including:

an iris matcher adapted to compare the enhanced image to a visible light image of the iris.

5. The system of claim 1, further including:

an enhanced iris code generation section adapted to generate an enhanced iris code based on the identified areas.

6. The system of claim 1, further including:

a biometric identification section adapted to identify a person based on the enhanced image.

7. The system of claim 1, wherein the maximum texture is identified based on texture measures of angular second movement, contrast, and entropy.

8. A system for generating iris images, comprising:

an iris image acquisition device adapted to acquire a visible light image of an iris;

a database adapted to store the acquired visible light iris image and transformation mappings;

a texture model section adapted to model the acquired visible light image in a texture model that clusters features from the acquired visible light image;

a mapping section adapted to select a transformation mapping from the database for each of the clusters;

an image transformation section adapted to apply the selected mappings to the acquired visible light image to generate a Near-Infrared equivalent representation of the iris; and

an image output section adapted to output the Near-Infrared equivalent representation of the iris.

9. The system of claim 8, further including:

an iris matching section adapted to compare the Near-Infrared equivalent with a Near-Infrared iris code.

10. The system of claim 8, further including:

a biometric identification section adapted to identify an image of a person based on the Near-Infrared equivalent.

More claims

11. The system of claim **8**, wherein the iris image acquisition device is a multispectral imaging device adapted to acquire spatially registered iris images simultaneously in four wavelengths.

12. The system of claim **8**, wherein the iris image acquisition device includes two stereo cameras adapted to acquire the visible light image and a corresponding Near-Infrared image of the iris.

13. The system of claim **12**, further comprising:
a depth map section adapted to generate a three-dimensional depth map of the acquired visible light image using a relative position of the two stereo cameras and an orientation of the two stereo cameras.

14. A method for generating iris images comprising:
acquiring a visible light image of an iris;
storing the acquired visible light iris image and transformation mappings in a database;
modeling the acquired visible light image by clustering textures from the acquired visible light image;
selecting mappings from the database for each of the clusters;
applying the selected mappings to the acquired visible light image to generate a Near-Infrared equivalent representation of the iris; and
matching the Near-Infrared equivalent with a Near-Infrared image of the iris.

15. The method of claim **14**, wherein the modeling further comprises clustering textures by applying k-means clustering.

16. The method of claim **14**, further including:
identifying an image of a person based on the matching.

17. The method of claim **14**, wherein the visible light image is retrieved from a database of previously-stored visible light images.

18. The method of claim **14**, wherein the visible light image is acquired by a multispectral imaging device.

19. The method of claim **14**, wherein the visible light image is acquired by two stereo cameras.

20. The method of claim **19**, further comprising:
generating a three-dimensional depth map of the acquired visible light image based on a relative position of the two stereo cameras and an orientation of the two stereo cameras.

Fairly complicated multispectral iris capture

- Ross et al., BTAS 2009
- 950-1650nm (waaaay out into the IR spectrum, SWIR)
- Silicon sensors don't work there.
  - XenIC InGaAs 320x256 FPA, Peltier cooler
  - Eight 100nm bandpass filters centered at 950, 1050… 1650nm (these, plus glass optics, can cause 50% transmission loss on the way to the sensor)
- Can't depend on "ambient" SWIR illumination
  - Tungsten-Krypton light source, 300-2200nm spectrum, filtered to 750-2200nm to avoid burning the iris)

Sample images

- Contrast and brightness variations by wavelength
  - 1400nm water absorption peak
- Eyelashes
- Limbus contrast
- Scleral vasculature

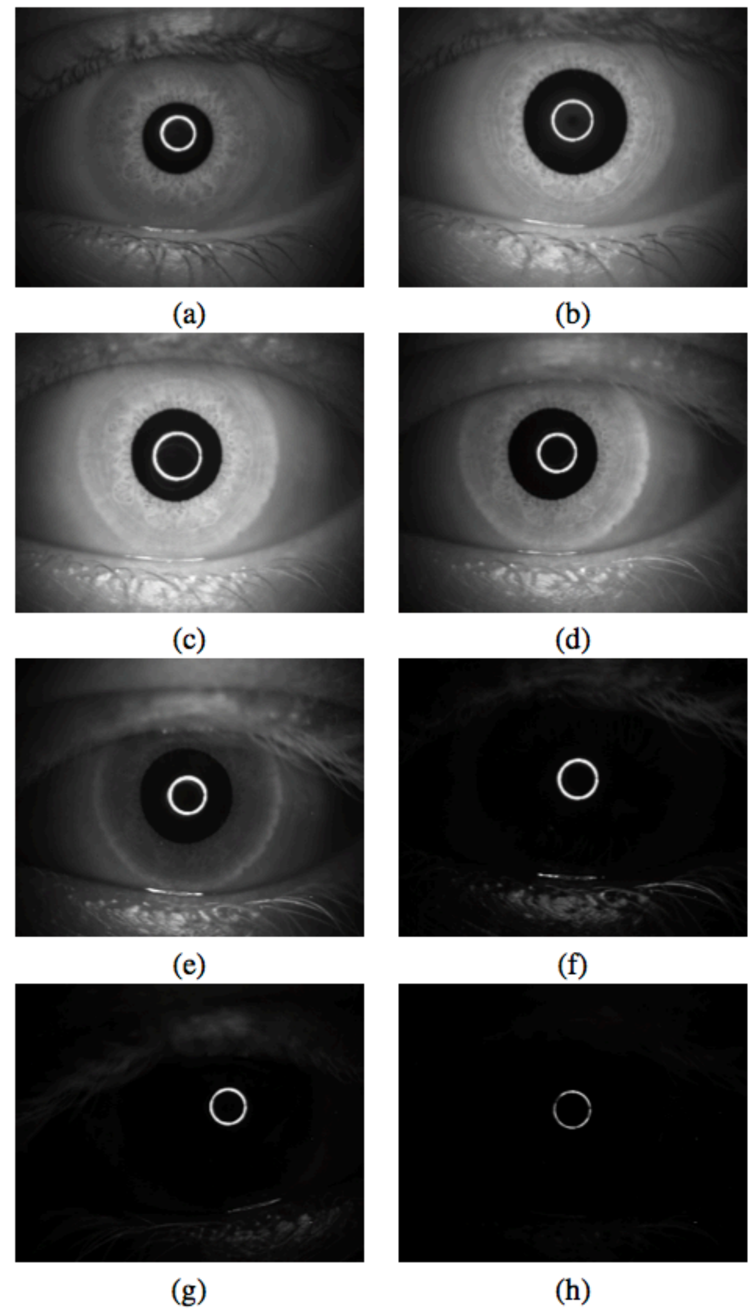


Fig. 4. Sample images obtained at wavelengths (a) 950nm, (b) 1050nm, (c) 1150nm, (d) 1250nm, (e) 1350nm, (f) 1450nm, (g) 1550nm, and (h) 1650nm.

Match scores for a Daugman-style matcher

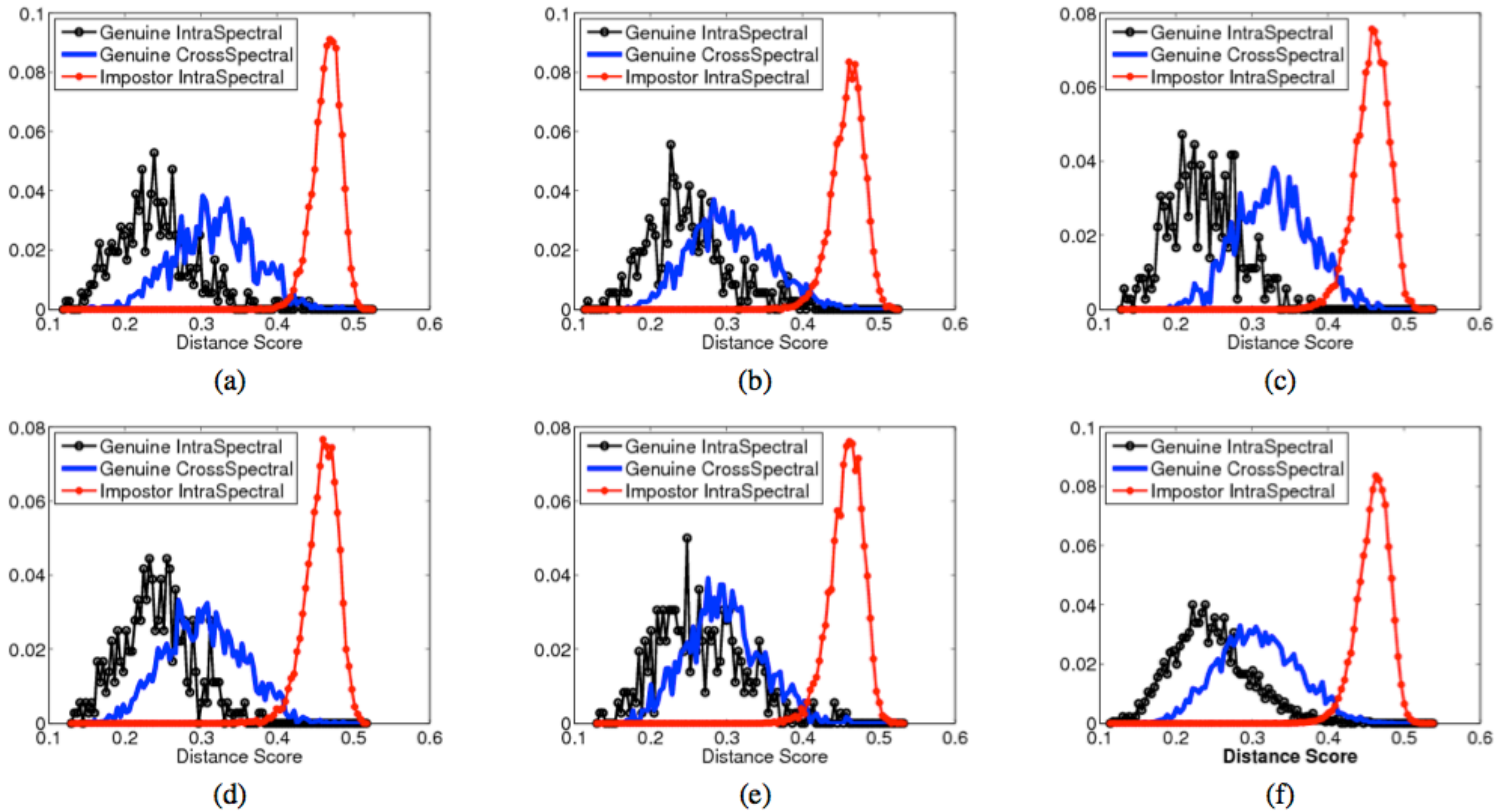


Fig. 10. Normalized histogram plots of genuine cross-spectral (blue dotted line), genuine intra-spectral (black line) and impostor intra-spectral (red line with markers) distance scores for (a) 950nm, (b) 1050nm, (c) 1150nm, (d) 1250nm, (e) 1350nm and (f) all the wavelengths combined.

Fusion (sum rule) of 5 spectral band scores

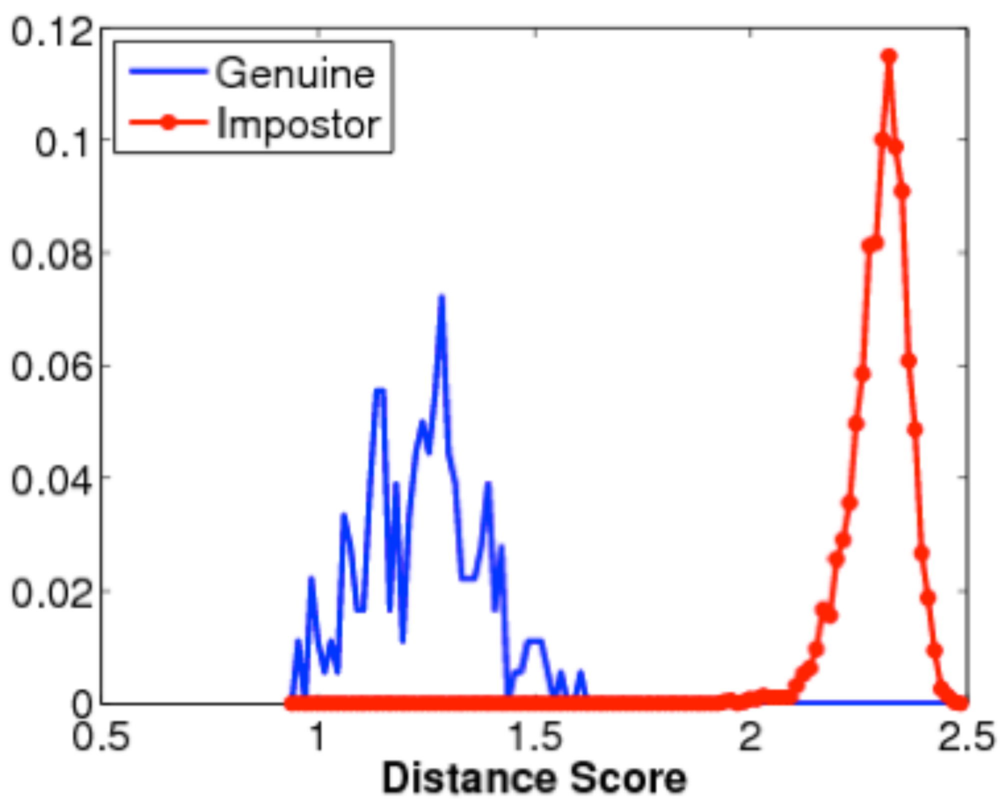


Fig. 11. The normalized histogram plot showing the result of fusing intra-spectral scores across the five spectral bands (950nm, 1050nm, 1150nm, 1250nm, 1350nm). Fusion using the simple sum rule results in good separation between genuine scores and impostor scores.

Active multispectral iris imaging

- USG effort to specify a multispectral iris capture system to foster research
- Illuminants: 12 wavelengths from 450-1550nm (Ngo et al, 2009 + Ross et al.)
- Spatial resolution (2 line pairs/mm): nontrivial to maintain over 1100nm range
- Depth of field spec: 1-1.5cm throughout (focus control over iris (not flat!)

Alternative (Ngo et al.)

8 wavelengths 405-1070nm

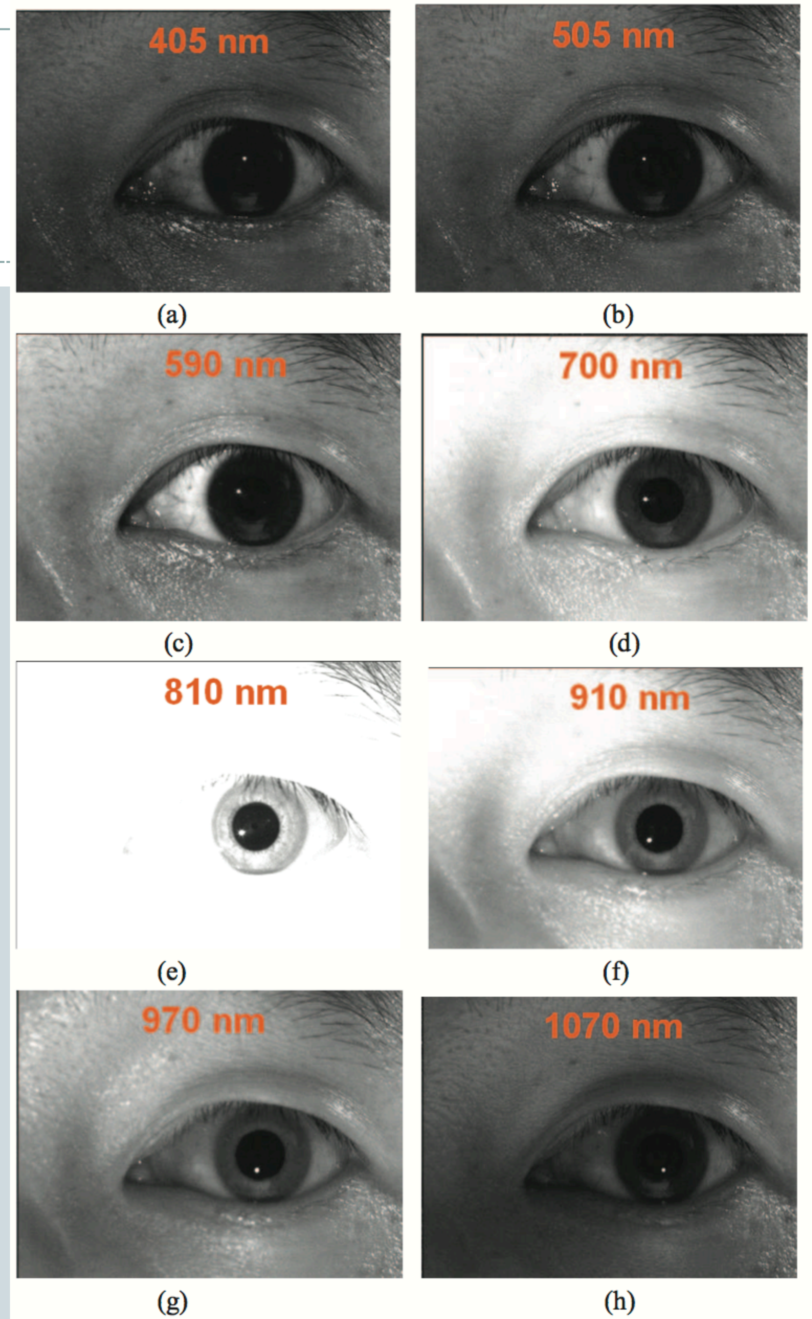


Fig. 6. Sample left iris images of a subject captured at wavelengths (a) 405 nm, (b) 505 nm, (c) 590 nm, (d) 700 nm, (e) 810 nm, (f) 910 nm, (g) 970 nm, and (h) 1070 nm.

True match scores by wavelength

- Ngo et al, 2009
- Degradation at shorter wavelengths: eye color
- Longer wavelengths: ?

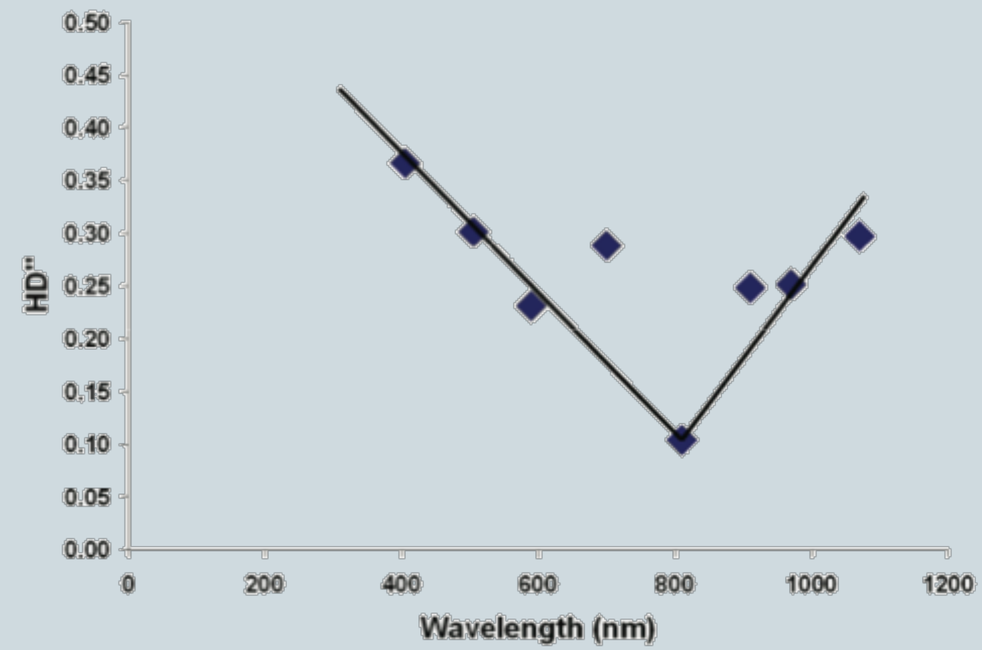


Fig. 8. Hamming distance of authentics for images taken at the same wavelength, as a function of that wavelength

Match score distribution for difference in wavelengths

- True matches look like false matches as wavelength difference increases

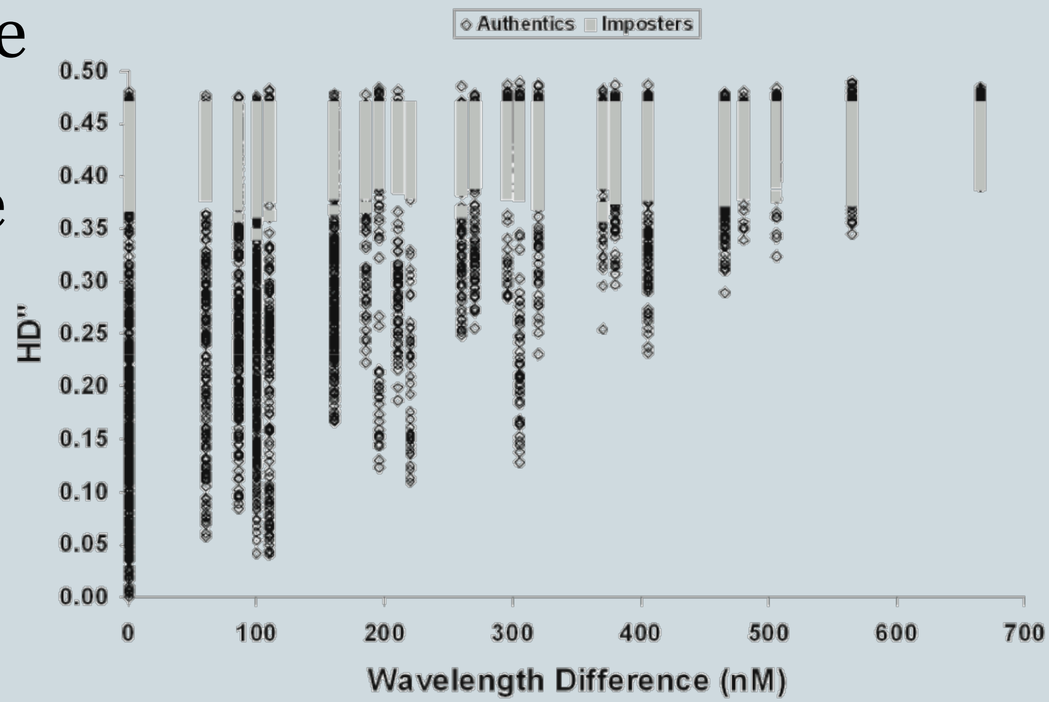
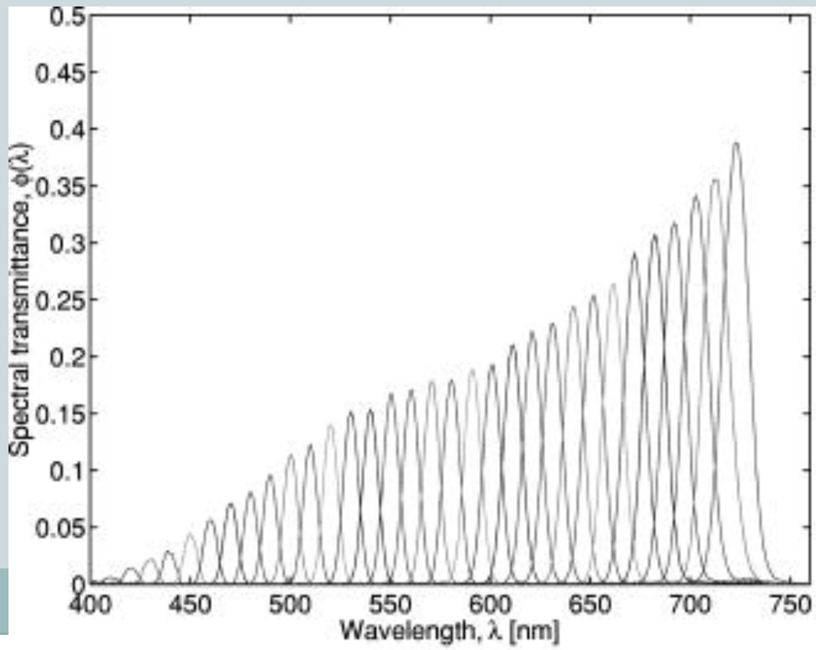
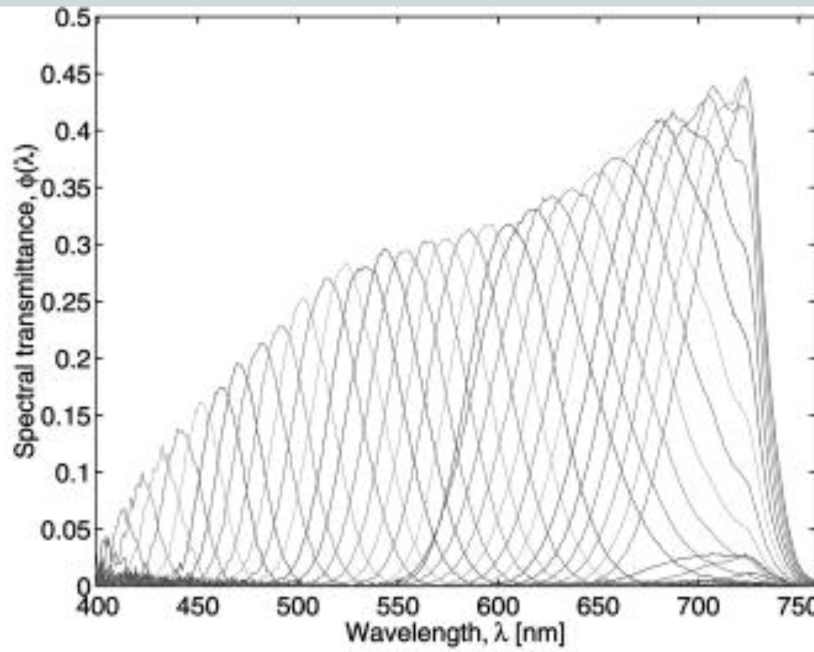


Fig. 9. Cross spectral analysis: Hamming distances for authentics and imposters as a function of the wavelength difference between images. Imposter data shadows the authentics data at larger differences in this plot.

Narrowband acquisition?

- Liquid crystal shutters can “tune” for wavelength (Hardeberg)
- Selectivity in narrow (5nm) and wideband (30nm) modes in figure below
- Utility for iris recognition not obvious





Iris + X multibiometrics

- Idea: multiple sites
- Iris + face: IOM, CFAIRS, AOptix, Retica, …
- Iris + fingerprint + face + palm (Neurotechnology MegaMatcher)
- Iris + iris (left/right) ? IOM
- Selection of fusion strategy is key

Signal Level Fusion

- Signal level fusion: form a new and/or “improved” signal from the inputs
- MANY possibilities
  - Concatenate samples and train/test using the same techniques (e.g., PCA on concatenated intensity/thermal images)
  - Synthesize an improved sample from multiple samples (e.g., iris image averaging)

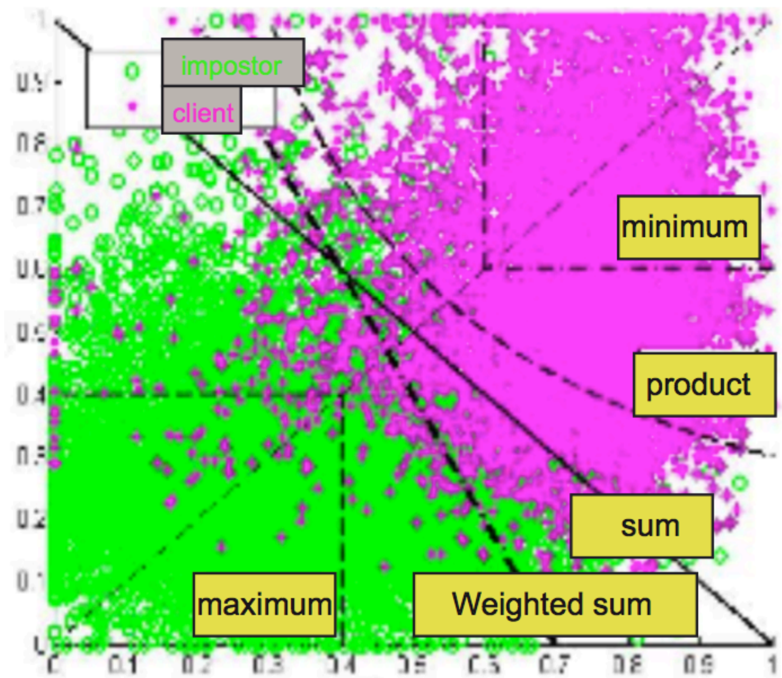
Score level fusion

- Most popular technique
- "Black box" view of matcher (hence useful for binary-only products like commercial SDKs)
- Fuse scores: sum, max, etc.
- Score normalization: both important and difficult
  - SDK 1: distance measure, 0.0 to 1.0
  - SDK 2: similarity measure, -1.0 to 1.0
  - …
- Minmax normalization, z-normalization, tanh normalization, etc.
- Or design classifier from unnormalized training data

Illustrating the difficulty (Lorene Allano, SudParis)

Performance of Combination methods

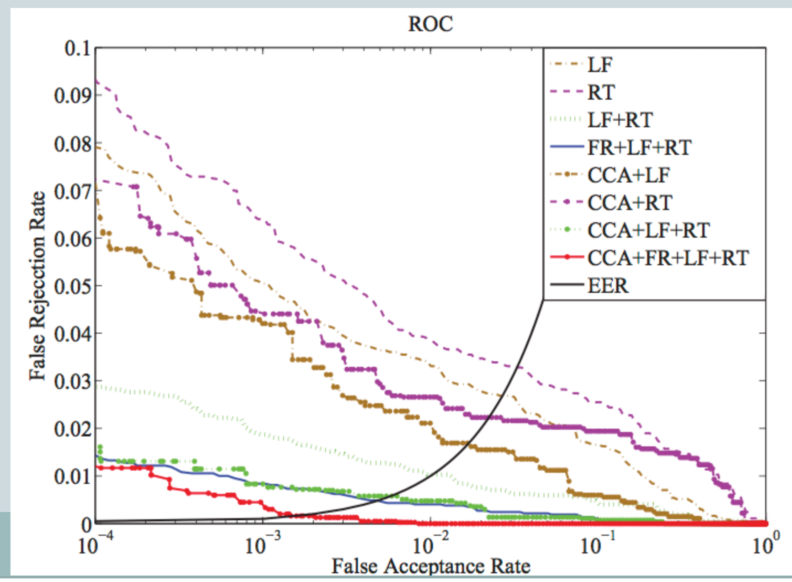
EER (%) intervalle de confiance à 90% ([min; max] en %)	Minmax	Znorm	Tanh
Somme	7.90 [7.43; 8.38]	8.22 [7.74; 8.70]	6.89 [6.44; 7.33]
Produit	11.42 [10.86; 11.98]	38.95 [38.09; 39.80]	6.90 [6.45; 7.35]
Minimum	18.89 [18.21; 19.58]	18.60 [17.92; 19.28]	13.99 [13.38; 14.60]
Maximum	8.95 [8.45; 9.45]	9.99 [9.46; 10.51]	11.30 [10.74; 11.85]
Mediane	10.99 [10.44; 11; 54]	9.65 [9.13; 10.17]	10.07 [9.55; 10.60]
Somme pondérée	6.23 [5.81; 6.66]	6.25 [5.83; 6.68]	6.13 [5.70; 6.55]



Product is very bad with Znorm and equivalent to sum with Tanh
Weighted sum gives the best results. The weights are computed for minimizing the error rate on the development database.
(It corresponds to the optimal linear separation)

Score-level fusion of face & iris

- Zhang et al., 2010
- Fuse low-quality face and iris scores
- Canonical Correlation analysis identifies a "good" subset of the low-quality data



Face + Iris: CFAIRS

(19) **United States**

(12) **Patent Application Publication**

Determan et al.

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(43) **Pub. Date: Mar. 27, 2008**

(54) **COMBINED FACE AND IRIS RECOGNITION SYSTEM**

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(21) Appl. No.: **11/681,752**

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(63) Continuation-in-part of application No. 11/275,703, filed on Jan. 25, 2006. Continuation-in-part of application No. 11/043,366, filed on Jan. 26, 2005. Continuation-in-part of application No. 11/372,854, filed on Mar. 10, 2006. Continuation-in-part of application No. 10/979,129, filed on Nov. 3, 2004, which is a continuation-in-part of application No. 10/655,124, filed on Sep. 5, 2003, now Pat. No. 7,183,895. Continuation-in-part of application No. 11/382,373, filed on May 9, 2006. Continuation-in-part of application No. 11/672,108, filed on Feb. 7, 2007. Continuation-in-part of application No. 11/675,424, filed on Feb. 15, 2007. Continuation-in-part of application No. 11/681,614, filed on Mar. 2, 2007. Continuation-in-part of application No. 11/681,662, filed on Mar. 2, 2007. Continuation-in-part of application No. 11/681,470, filed on Mar. 2, 2007. Continuation-in-part of application No. 11/681,505, filed on Mar. 2, 2007. Continuation-in-part of application No. 11/681,251, filed on Mar. 2, 2007. Continuation-in-part of application No. 11/681,751, filed on Mar. 2, 2007.

(60) Provisional application No. 60/778,770, filed on Mar. 3, 2006. Provisional application No. 60/807,046, filed on Jul. 11, 2006. Provisional application No. 60/647,270, filed on Jan. 26, 2005. Provisional application No. 60/807,046, filed on Jul. 11, 2006.

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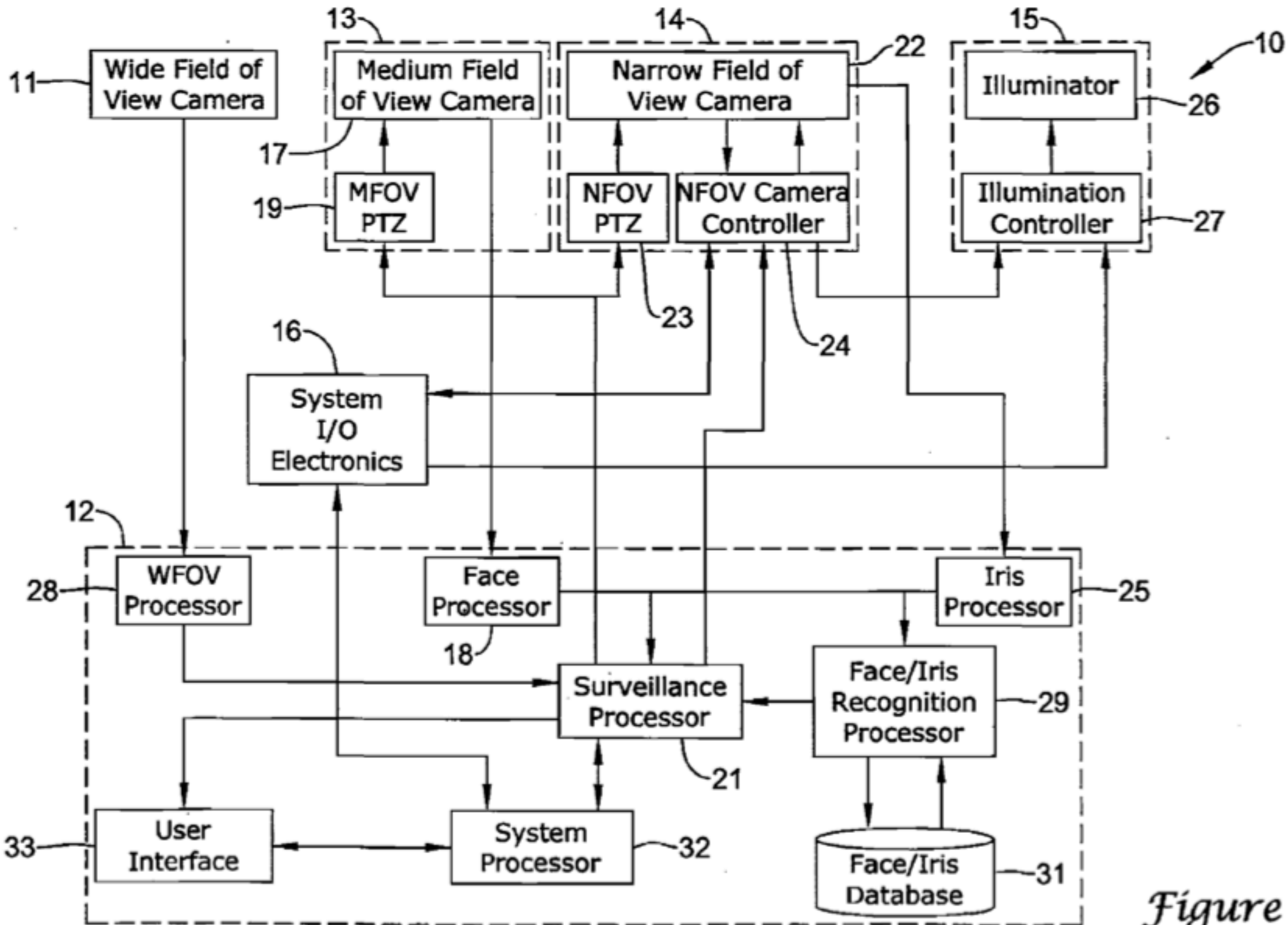
(52) **U.S. Cl.** **382/117**

(57) **ABSTRACT**

A system using face and iris image capture for recognition of people. The system may have wide field-of-view, medium field-of-view and narrow field-of-view cameras to capture images of a scene of people, faces and irises for processing and recognition. Matching of the face and iris images with images of a database may be a basis for recognition and identification of a subject person.



10
11
Wide Field of View Camera
13
Medium Field of View Camera
17
MFOV PTZ
19
14
Narrow Field of View Camera
22
NFOV PTZ
23
NFOV Camera Controller
24
15
Illuminator
26
Illumination Controller
27
16
System I/O Electronics
12
WFOV Processor
28
Face Processor
18
Iris Processor
25
Surveillance Processor
21
Face/Iris Recognition Processor
29
User Interface
33
System Processor
32
Face/Iris Database
31

Figure 1

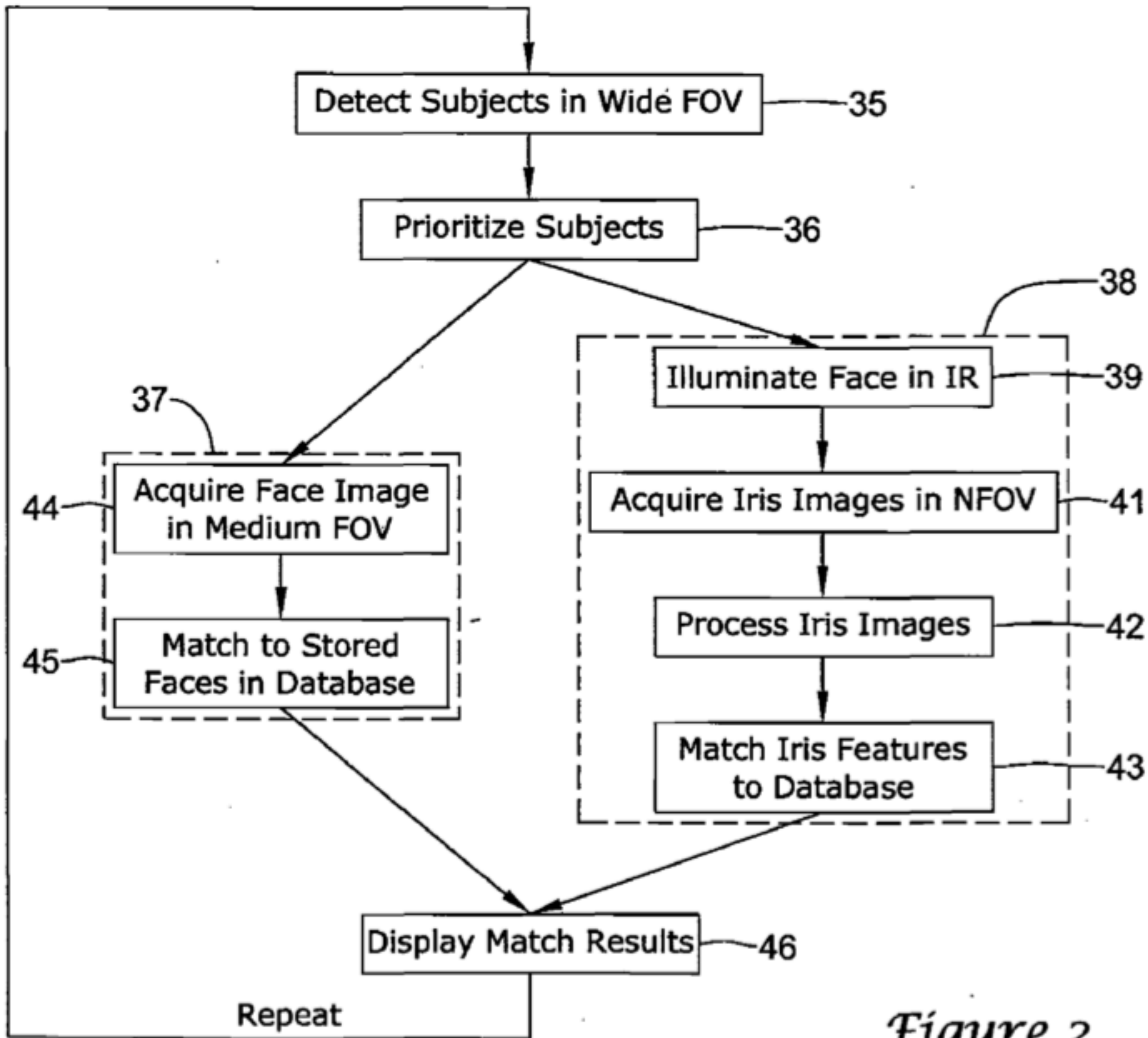

Detect Subjects in Wide FOV
35
Prioritize Subjects
36
38
Illuminate Face in IR
39
37
Acquire Face Image in Medium FOV
44
Acquire Iris Images in NFOV
41
Process Iris Images
42
Match to Stored Faces in Database
45
Match Iris Features to Database
43
Display Match Results
46
Repeat

Figure 2

Claims

What is claimed is:

1. A subject recognition system comprising:

a wide field-of-view camera;

a medium field of view camera;

a narrow field of view camera; and

a processing system connected to the wide field-of-view, medium field of view, and narrow field of view cameras.

2. The system of claim 1, further comprising a controller for driving a zoom of the narrow field of view camera.

3. The system of claim 2, wherein:

the wide field-of-view camera is for locating positions and ranges of subjects in an area;

the medium field of view camera is for capturing images of the subjects; and

the narrow field of view camera is for capturing images of iris features of the subjects.

4. The system of claim 3, wherein:

the subjects are people; and

the features are irises.

5. The system of claim 4, wherein the medium field of view camera is for capturing images of faces of the people.

6. The system of claim 3, wherein the wide field of view camera is for estimating a distance between the cameras and the subjects.

7. The system of claim 3, wherein the distance to the subject may be inferred by stereo or from a calibrated camera and anthropometric knowledge.

8. The system of claim 3, wherein a correct zoom factor of the narrow field of view is estimated for capturing iris images.

9. The system of claim 5, wherein the processing system comprises a mechanism for storage and retrieval of images.

10. The system of claim 9 further comprising:

a mechanism for face and iris matching and/or enrolling connected to the processing system; and

an interface module connected to the mechanism for face and iris matching and/or enrolling and to the wide field of view camera, the medium field of view camera and the narrow field of view camera.

Claims 2

11. The system of claim 10, wherein the interface module comprises an iris processor connected to the narrow field of view camera and to the mechanism for face and iris matching and/or enrolling.

12. The system of claim 10, further comprising an illumination system connected to the interface module.

13. The system of claim 12, wherein the illuminator is an infrared iris illuminator.

14. A method of detecting and recognizing subject, comprising:

detecting one or more subjects in a scene;

acquiring face images of the one or more subjects;

acquiring iris images of the one or more subjects;

matching face images to stored faces in a database; and

matching iris images to iris images in a database.

15. The method of claim 14, wherein a level of recognition of a subject comprises a matching of a face image of the subject and a matching of an iris image of the subject with corresponding images, respectively, in a database.

16. The method of claim 14, further comprising illuminating faces of the one or more subjects with infrared light for acquiring iris images.

17. The method of claim 14, further comprising prioritizing the subjects for recognition after detecting one or more subjects in a scene.

18. The method of claim 14, wherein:

the detecting the one or more subjects is in a wide field-of-view;

the acquiring the face images is in a medium field-of-view;

the acquiring the iris images is in a narrow field-of-view;

the detecting the one or more subjects in a wide field-of-view, acquiring face images in a medium field-of-view and acquiring iris images in a narrow field-of-view are achievable with two or less image sensors.

19. A combined biometrics recognition system comprising:

a camera;

a camera controller connected to the camera; and

a feature processor connected to the camera; and

wherein the camera has an adjustable field-of-view for acquiring one or more subjects in a scene and their features.

Claims 3

20. The system of claim 19, wherein:

the field-of-view of the camera is adjustable to a wide field-of-view for acquiring an image of the one or more subjects; and

the field-of-view of the camera is adjustable to a narrow field-of-view for acquiring an image of the at least one feature of a subject.

21. The system of claim 20, wherein:

the one or more subjects are persons; and

the at least one feature of a subject is a face and/or an iris.

22. The system of claim 21, further comprising a feature recognition processor connected to the camera controller.

23. The system of claim 22, further comprising:

a storage mechanism connected to the feature recognition processor; and

wherein the feature recognition processor is for matching images of features from the camera with images of features from the storage mechanism.

24. The system of claim 23, further comprising an infrared illumination system for illuminating features of images to be acquired by the camera.

AOptix/Aware

- AOptix: 2 meter standoff iris recognition
- Aware: Face recognition SDK

- Joint demo at BCC, 2010
- How did they fuse?

Feature-level fusion

- Extract comparable sets of features from the various modes; concatenate them
- Face + iris: SIFT features on face and in unwrapped iris texture (Rattani and Tistarelli, ICB 2009). "Chimera" subjects, small databases…

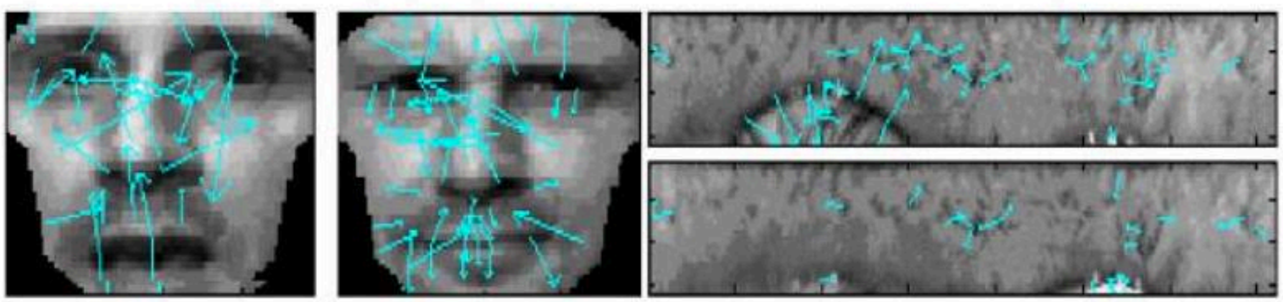
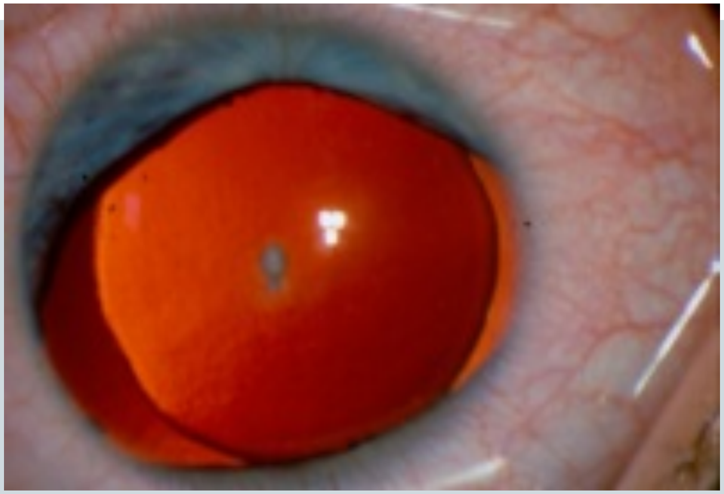


Fig. 1. Shows extracted SIFT Features from the face and iris images. Even with the strong intra-class variations many common SIFT Features can be easily noticed for both the biometrics.

Bonus: eye diseases and conditions that can affect iris imaging

- Eye diseases affecting iris
- Anopthalmos: missing eye
- Aniridia: absence of iris
- Micropthalmia: abnormally small eye

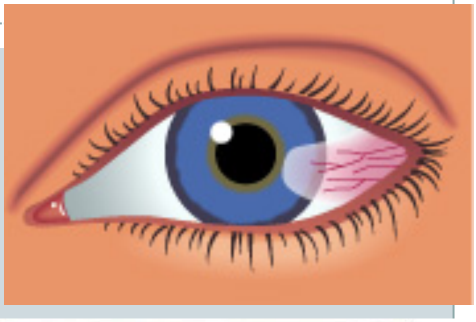


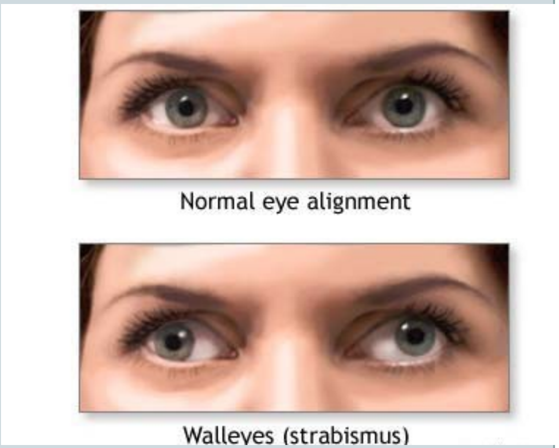
- Iris coloboma: hole (usually developmental)

Images: Ophtec.com

Eye diseases and conditions

- Rapid blinking (blepharospasm, CNS)
- Iris occlusion by tissue (pterygium; vascularized fibrous tissue "wings")
- Strabismus (misalignment; crossed eyes or wall eyes)
- Fungal keratitis (infection of cornea)

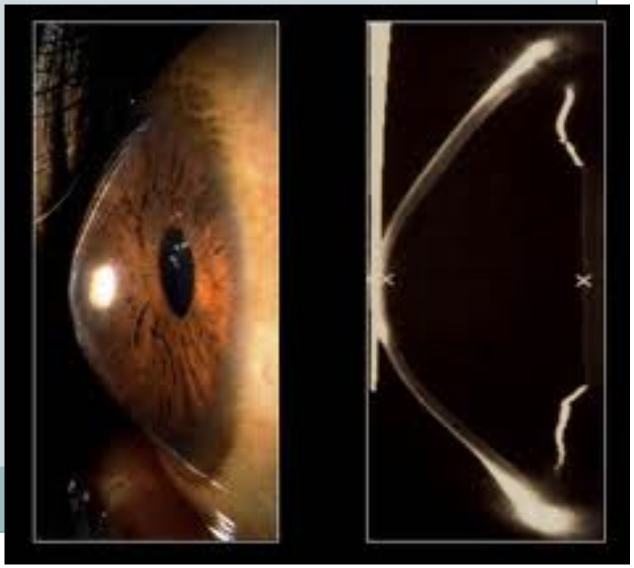




Eye diseases and conditions

- Conjunctivitis, canaliculitis, blocked tear duct, ectropion

- Keratoconus: corneal degeneration



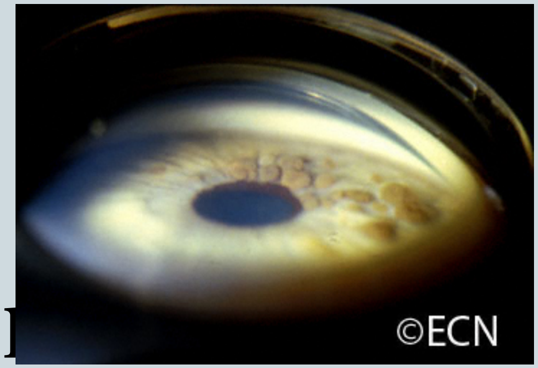
Eye diseases and conditions

- Non-orbital occlusion: ptosis, dermatochala

- Pediculosis (lice!)
- Abrasion from eyelashes (entropion)
- Heterochromia

Eye diseases and conditions

- Eye tumor: dermoid cyst, hemangioma, melanoma, nevus (precursor)



- Nonresponsive pupils: cranial nerve
Argyll-Robertson syndrome (subsequent to syphilis), Horner's syndrome (nerve paralysis on one side of the face)

Right Horner's sydrome.

Figure. Argyll Robertson pupil.

Eye diseases and conditions

- Pupil size difference from left to right: anisocoria (glaucoma, trauma, etc.) [David Bowie]

- Nystagmus, opsoclonus: involuntary eye movement disorders
- Parinaud dorsal midbrain syndrome: inability to look up
- Myokymia: eyelid tic (common)
- Arcus: white ring near limbus: cholesterol

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