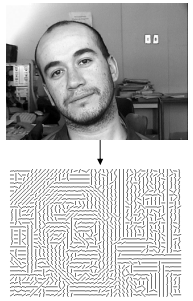
Detección de Rostros

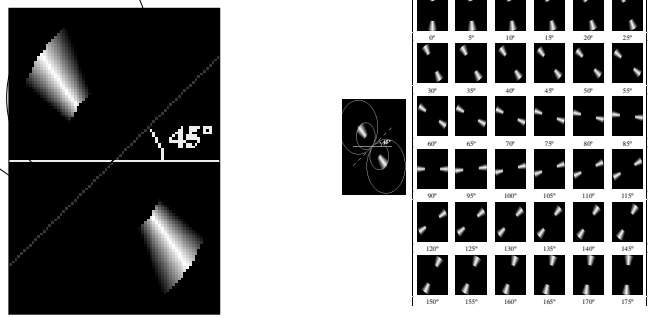
Coarse Face Detection



Window size = 7 pixels

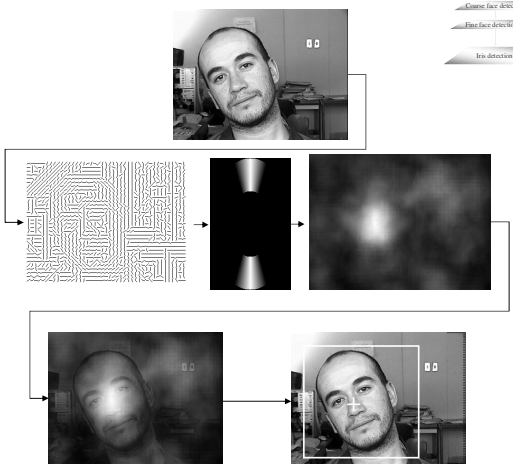
$$\vec{n}(i,j) = n_i\hat{i} + n_j\hat{j} \quad ,$$
$$n_i = \frac{I_n(i-1,j-1) + I_n(i+1,j-1) - I_n(i-1,j+1) - I_n(i+1,j+1)}{4} \quad , \qquad (1)$$
$$n_j = \frac{I_n(i+1,j-1) + I_n(i+1,j+1) - I_n(i-1,j-1) - I_n(i-1,j+1)}{4} \quad .$$

Coarse Face Detection

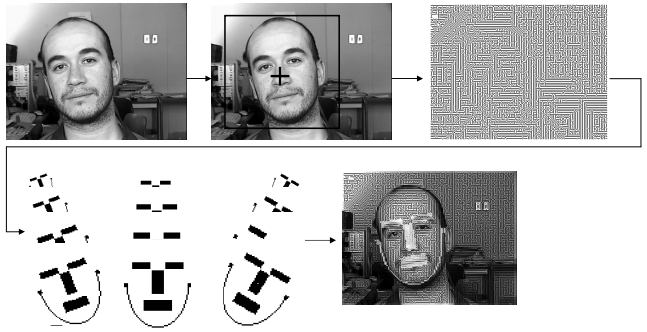


$$T = \left\{ (x,y) \;\middle|\; (\text{min range})^2 \le \left(\frac{x - x_0}{a}\right)^2 + \left(\frac{y - y_0}{b}\right)^2 \le (\text{max range})^2 \right.$$
$$\left. \text{abs}\left(\text{arctg}\left(\frac{y - y_0}{x - x_0}\right) - \varphi\right) \le \frac{\theta}{2} \right\} \quad (1)$$

Coarse Face Detection



Fine Face Detection



$$I_{T_{FRib}}(i_o, j_o) = \frac{\sum [I_{ROI}(i,j) \cdot a(i,j) - (1 - I_{ROI}(i,j)) \cdot 90]}{N_{T_{FRib}}} \quad (2)$$

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Real-Time Iris Detection on Coronal-Axis-Rotated Faces

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***Abstract*—Real-time face and iris detection on video sequences is important in diverse applications such as, study of the eye function, drowsiness detection, virtual keyboard interfaces, face recognition, and multimedia retrieval. In this paper, a real-time robust method is developed to detect irises on faces with coronal axis rotation within the normal range of −40° to 40°. The method allows head movements with no restrictions to the background. The method is based on anthropometric templates applied to detect the face and eyes. The templates use key features of the face such as the elliptical shape, and location of the eyebrows, nose, and lips. For iris detection, a template following the iris–sclera boundary shape is used. The method was compared to Maio–Maltoni's and Rowley's methods for face detection on five video sequences (TEST 1). The method was also assessed in an additional set of five video sequences for iris detection (TEST 2). Results of correct face detection in TEST 1 were above 99% in three of the five video sequences. The fourth video sequence reached 97.6% and the third 90.6%. In TEST 2, the iris detection was above 96% in all five video sequences with two above 99.7% and two at 100%. Face size estimation is also** on helmets, electrodes that measure the activity of the eyeball, light reflected by the cornea (punkinje images), or near-infrared (NIR) imaging [4], [5], [33]. Lately, video cameras have been used as an alternative automated method for monitoring eye movements in a nonintrusive manner.

Many noninvasive methods for eye gaze estimation need the face position first. Face position estimation is a very important problem in the field of computer vision [32]. Several methods have been developed for this problem using NIR [4], [33], neural networks [25], [28], [29], skin color [11], [31], and templates [10], [16], [19]. Neural-network-based methods have been used to recognize [24] and detect faces [28], [29]. In [28], a 20×20 window is used to scan the input image looking for faces in different resolutions. The output goes to a neural network of 400 inputs and 36 outputs to detect a rotation angle. The method is computationally intensive in training and processing time, be-

Template Generation for Real-Time Face Detection

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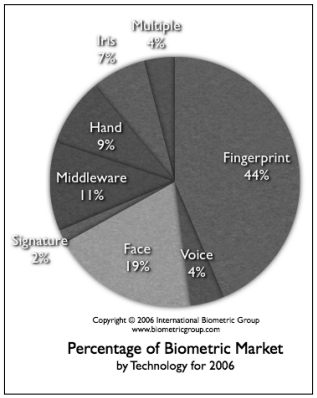
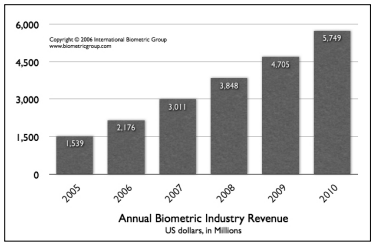
Face Detection

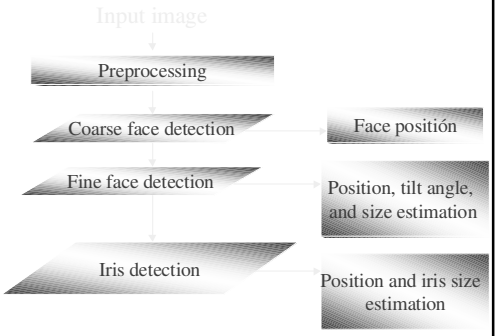
- Applications:
  - Face recognition
  - Man-Machine interfaces (control devices)
  - Surveillance applications – watch list
  - User verification procedures

Biometric Market- Face

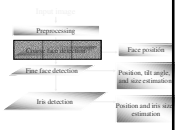


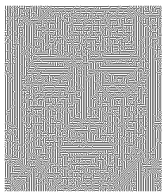


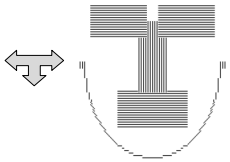
Previous Approach: Templates



Previous Approach: Templates

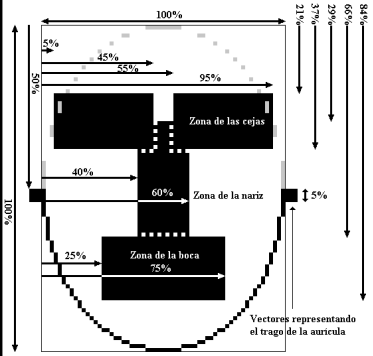




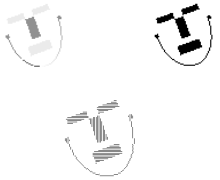


Directional image *Anthropometric template*

Previous Approach: Templates



Fine face template



Fine face template construction

- Anatomical characteristics measured in fine directional images:
  - Eyebrows
  - Nose
  - Mouth
  - Chin

Objective of this research

- Improve templates using information from directional image.
- Build an interface to detect and track eye position on frontal faces.
- Not controlled background
- Real time processing
- Minimally invasive

Template Generation by Component Maximization for Real Time Face Detection

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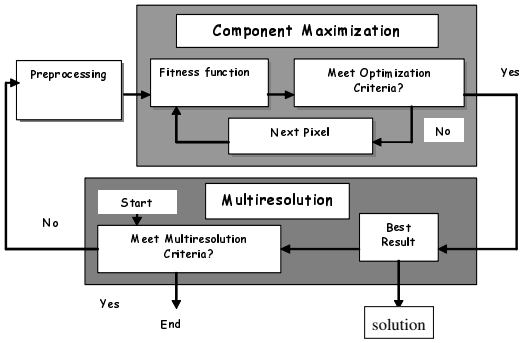
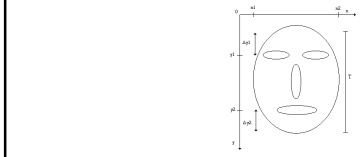
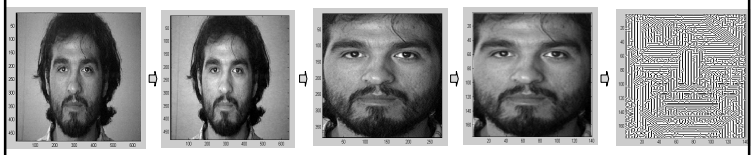
Methods



Methods





Methods

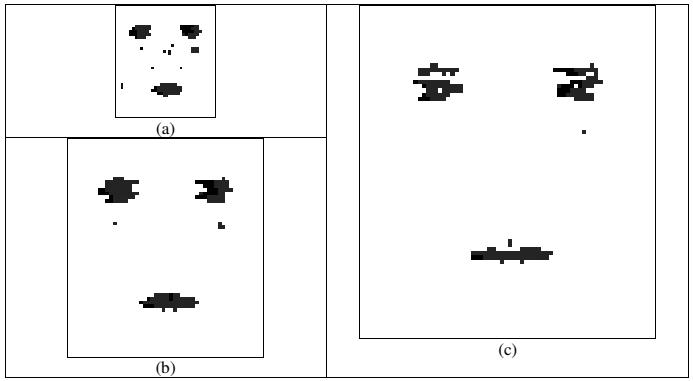
Line integral components

$$f_{v,l,m}^{k} = \frac{\sum_{h=0}^{N_R-1} \left(I_{ref_{h,l,m}} \cdot \alpha_{v,h,l,m} - \left(1 - I_{ref_{h,l,m}}\right) \cdot 90° \right)}{N_R}$$

$$g_{l,m} = \max_{v=0°,\ldots,180°} \left\{ f_{v,l,m}^{k} \right\} \qquad I_{d_{l,m}} = \begin{cases} I_{ref_{l,m}} = 1 \,\&\, I_{\alpha_{l,m}} = v & \text{, if } g_{l,m} > T_g \\ I_{ref_{l,m}} = 0 & \text{, otherwise} \end{cases}$$

• templates are computed for different face eccentricity and size

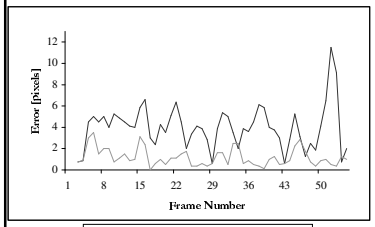
Results

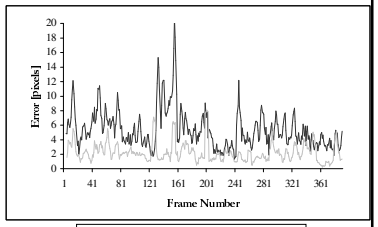


Templates for 103 individuals for face sizes (height): (a) 120 pixels, (b) 180 pixels, and (c) 240 pixels. Face eccentricity is 90%.

Results

Face size error: anthropometric vs. CM





Purdue database (55 images)

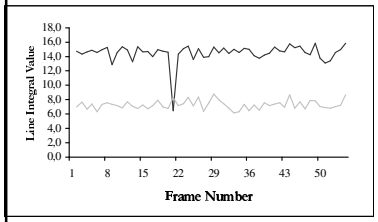
Caltech database (386 images)

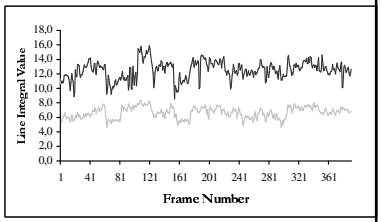
Anthrop. templates

CM templates

Results

Line integral value : anthropometric vs. CM





Purdue database (55 images)

CM templates

Anthrop. templates

Caltech database (386 images)

Results

Total number of pixels in the CM and in the Anthropometric templates.

Templates	Pixels
CM	9320
Anthropometric	53504

Computational time: CM templates: 0.0092 s. Anthropometric templates: 0.031 s .

Face and iris correct detection for the CM and Anthropometric templates

Database	Number of Images	Face Detection Templates	
		CM	Anthropometric
Purdue	55	98%	84%
Caltech	386	97%	66%
Total	441	97%	68%

Conclusions

- A new method has been proposed to generate templates to detect faces
- The new method is based on maximizing the response of the template applied to the face directional image
- The method was applied to images of two face databases (Purdue and Caltech) with improved results of the new template relative to the previous anthropometric templates

Conclusions

- The new templates showed improvements in:
  - face size estimation
  - larger line integral value
  - fewer number of points (faster computational time)
  - improved face detection rate

Face Detection using PSO Template Selection

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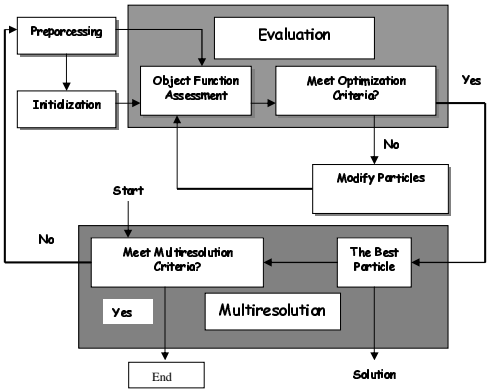
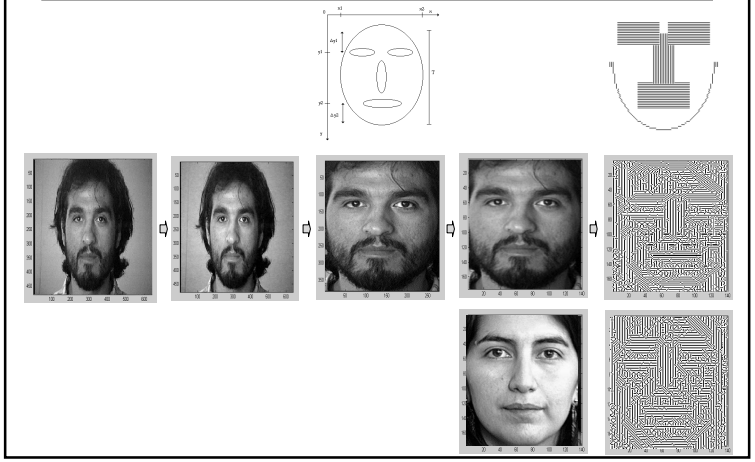
Methods: template generation (PSO)



Methods: Preprocessing



Methods

Line integral for particle i (fitness function):

$$f_i^k = \frac{\sum_{h=0}^{N_R-1}\sum_{l=0}^{N_W}\sum_{m=0}^{N_H} IM_{l,m,i}\cdot\left(I_{ref_{h,l,m}}\cdot\alpha_{i,h,l,m} - \left(1-I_{ref_{h,l,m}}\right)\cdot 90°\right)}{N_R\cdot PM_i}$$

$$\alpha_{i,j,l,m} = 90° - 2\cdot\min\left(|\,\mathrm{MM}_{i,l,m} - I_{\alpha_{h,l,m}}\,|, 180° - |\,\mathrm{MM}_{i,l,m} - I_{\alpha_{h,l,m}}\,|\right)$$

$I_{\alpha_{h,l,m}}$: angle at point *(l, m)* for face *h*

$MM_{i,l,m}$: *angle at point (l, m) of particle ,*

$I_{\alpha_{h,l,m}}$: *angle at point (l, m) of face .*

PM_i: total number of points of particle i.

Methods

The particles are changed according to:

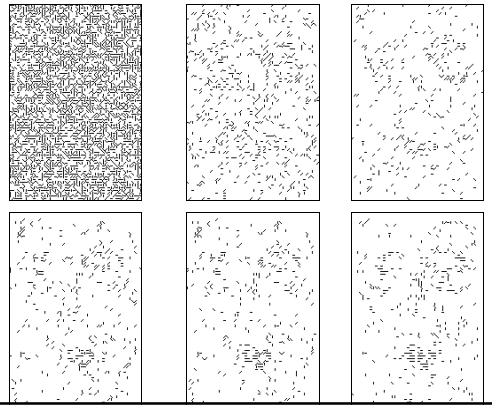
$$V_{i,l,m}(t+1) = w\cdot V_{i,l,m}(t) + \varphi_1\cdot\left(P_{i,l,m} - X_{i,l,m}(t)\right) + \varphi_2\cdot\left(P_{g(i),l,m} - X_{i,l,m}(t)\right)$$

$$X_{i,l,m}(t+1) = X_{i,l,m}(t) + V_{i,l,m}(t+1)$$

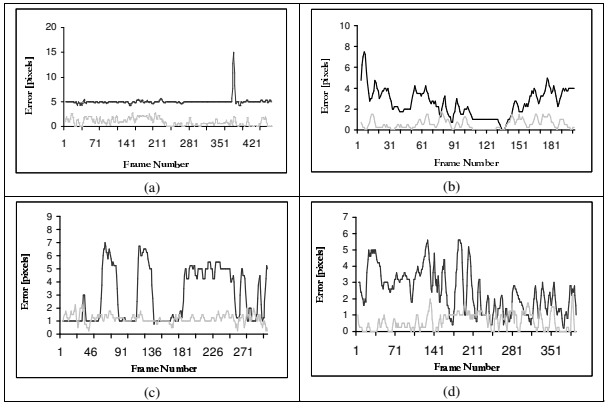
• templates are computed for different face eccentricity and size

Results

Evolution of the PSO algorithm for 1,800 iterations. (a) Initial randomly initialized template. (f) Final template after 1,800 iterations

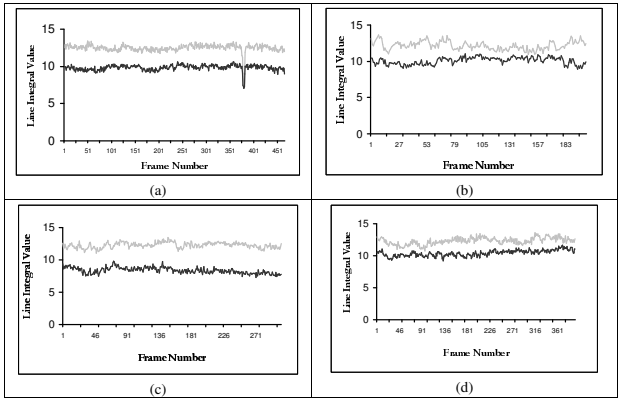


Results: Face size error: Anthropometric vs. PSO



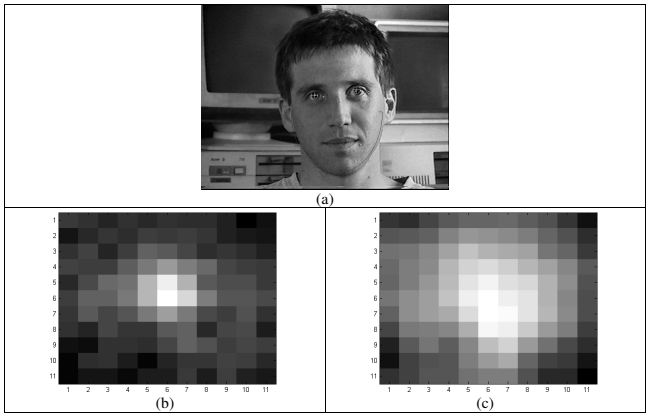
Error in the face size estimation between the Anthropometric templates (black) and the PSO Template (gray level) applied to two video-sequences.

Results: Line integral value : anthropometric vs. PSO



Line integral value for the PSO Template (gray level) and the Anthropometric Template (black) applied to four video-sequences.

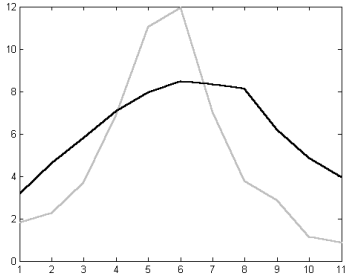
Results: Line integral value localization: anthr vs. PSO



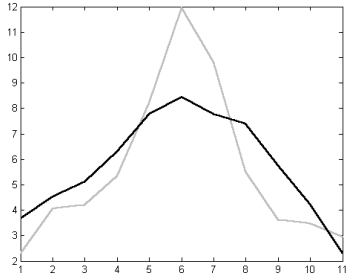
PSO template *Anthropometric template*

Results

Line integral value : spatial localization



Line integral value along the *x* axis with PSO Template (gray) and Anthropometric Template (black)



Line integral value along the y axis with PSO Template (gray) and Anthropometric Template (black)

Results

Total number of pixels in the PSO and in the Anthropometric templates.

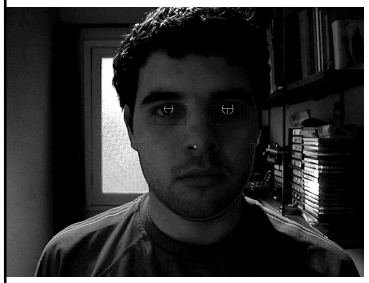
	Video Sequence				
Templates	1	2	3	4	Average
Anthropometric	22354	26298	24606	24456	24429
PSO	14382	14054	19102	14575	15528

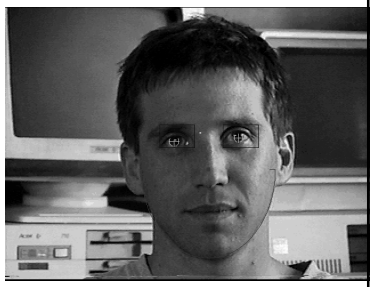
Computational time: PSO templates: 0.019 s. Anthropometric templates: 0.029 s (Athlon XP 2000+, 1.67GHz computer with 512 MB RAM).

Face and iris correct detection for the PSO and Anthropometric templates

Video Sequence	Number of Frames	Face Detection		Iris Detection	
		Templates		Templates	
		PSO	Anthropometric	PSO	Anthropometric
1	466	99%	98%	100%	100%
2	202	100%	100%	100%	100%
3	306	100%	100%	94%	92%
4	395	100%	100%	100%	100%
	1369	100%	99%	99%	98%

Result: Applications to video sequences





Conclusions

- A new method has been proposed to generate templates to detect faces
- The new method is based on PSO and was applied to the face directional image
- The method was applied to generate templates in 4 video sequences and results of the new templates improved relative to the previous anthropometric templates

Conclusions

- The new templates showed improvements in:
  - face size estimation
  - larger line integral value and improved spatial localization
  - fewer number of points (faster computational time)
  - improved face and iris detection rate