Average of Synthetic Exact Filters

Jose I. Pacheco

Department of Mathematics and Statistics
California State University, Long Beach
jpachec2@csulb.edu

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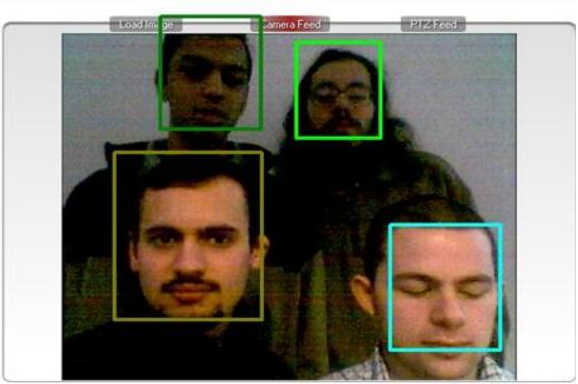
Outline

First step: Face Registration

How?

Find the eyes



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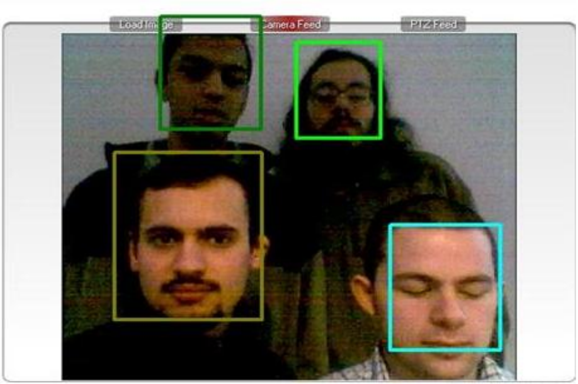

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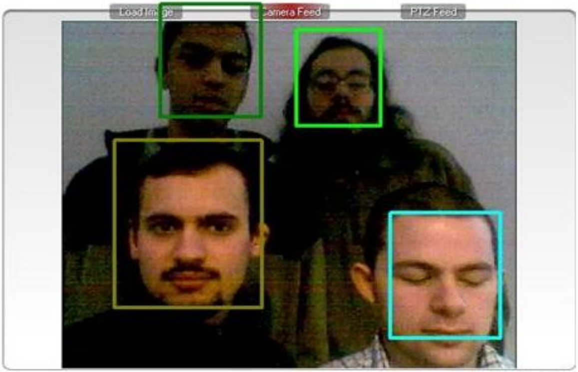
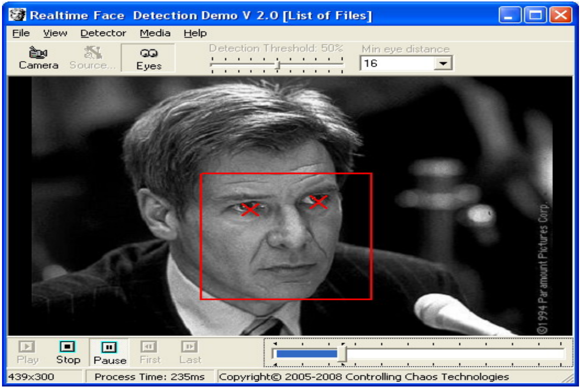


Eye Localization

Goal:

Return pixel coordinates of eye center to within some tolerance



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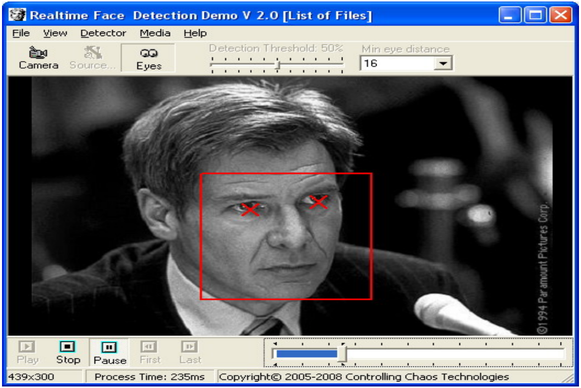

Problems

Two types of problems:

1. Prior Knowledge (e.g. location of face, known region of eye)
2. No Prior Knowledge

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Convolution vs. Correlation

Convolution:

$$(f * g)[n] = \sum_{m=-\infty}^{\infty} f[m] \cdot g[n-m]$$

Correlation:

$$(f \otimes g)[n] = \sum_{m=-\infty}^{\infty} f^*[m] \cdot g[n+m]$$

Convolution/Correlation Theorem

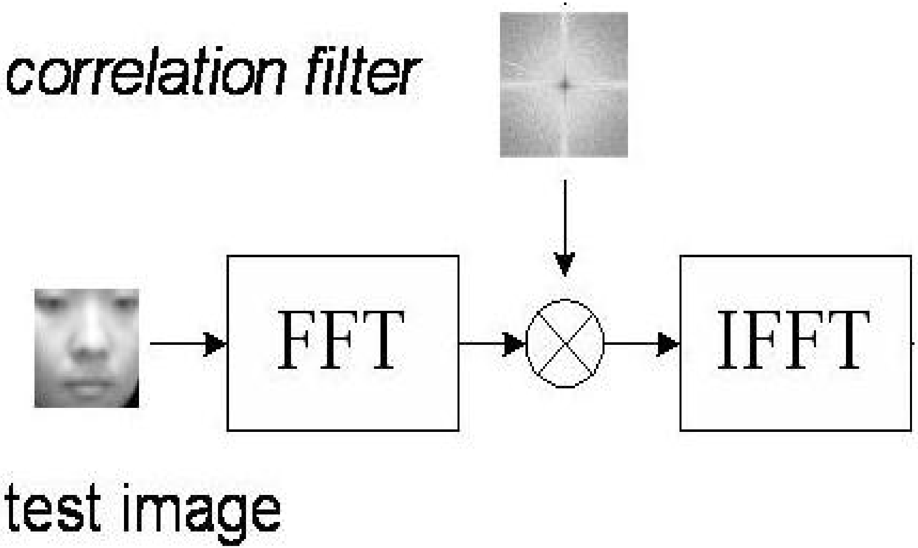
Convolution Theorem:

$$\mathcal{F}(f * g) = \mathcal{F}(f) \cdot \mathcal{F}(g)$$

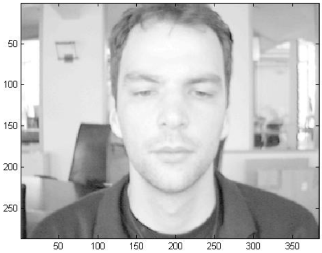
"Correlation" Theorem:

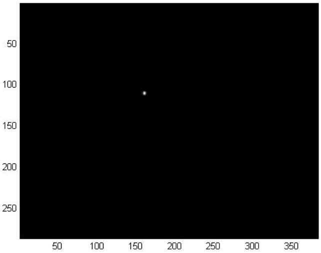
$$\mathcal{F}(f \otimes g) = [\mathcal{F}(f)]^* \cdot \mathcal{F}(g)$$

Filtering Process



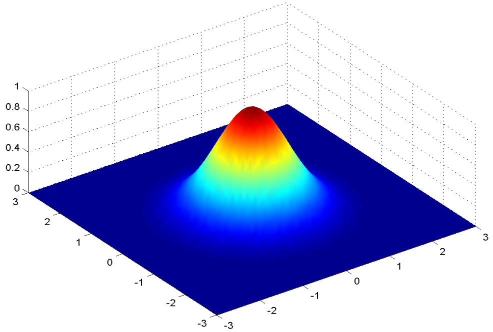
How to Construct Filters





Desired Output: Gaussian

$$g_i(x,y) = e^{\frac{-(x-x_i)^2-(y-y_i)^2}{\sigma^2}}$$



Proof

Let $f_i(x, y)$ be an image in training set and let $g_i(x, y)$ be desired output. We want filter $h_i(x, y)$ such that

$$f_i(x, y) * h_i(x, y) = g_i(x, y)$$

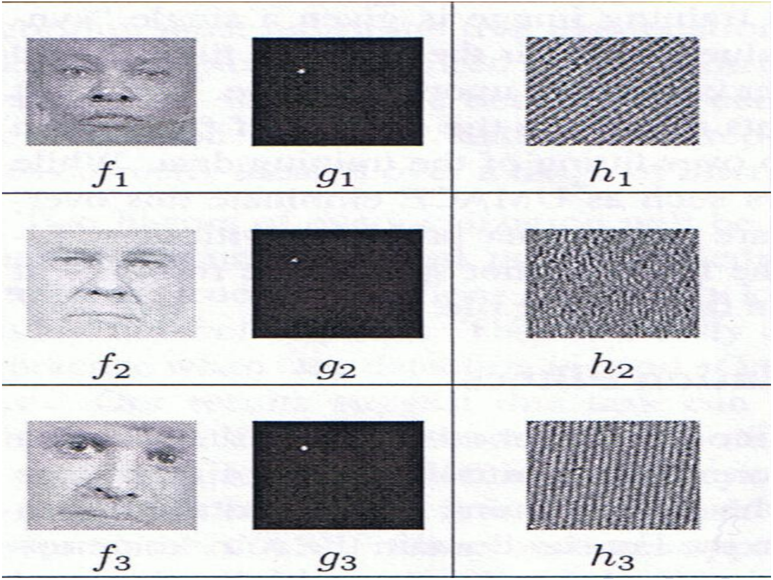
Taking Fourier Transform of both sides and applying Convolution Theorem

$$F_i(x, y) \cdot H_i(x, y) = G_i(x, y)$$

or

$$H_i(x, y) = \frac{G_i(x, y)}{F_i(x, y)}$$

Exact Filters



Averaging

Now that we have h_i let us calculate their average

$$h = \sum_{i=1}^{N} h_i(x, y) \tag{1}$$

Now that we have filter we can apply it.

Averaging?

But wait...why average?

Averaging emphasizes common features and suppresses those specific to an image.

Final Filter

$$1/N \sum_{i=0}^{N} h_i$$

Experimentation

- Left Eye
- Feret Database
- 1024 images for training set
- 1699 images for testing set
- Similarity transforms: rotations($\pm\frac{\pi}{6}$), scaling(1.0 ± 0.1), translations(± 4.0)
- Error $D = \frac{||P_l - M_l||}{||M_l - M_r||}$
- $D < .10$ is a success

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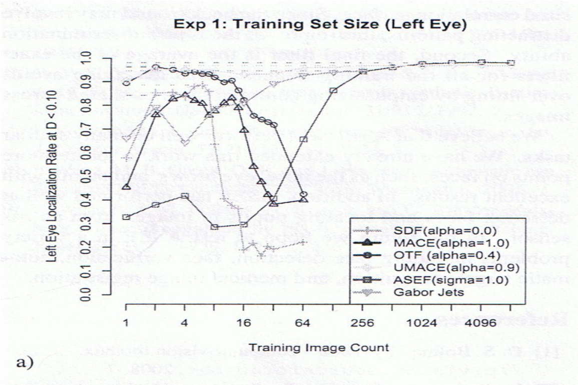
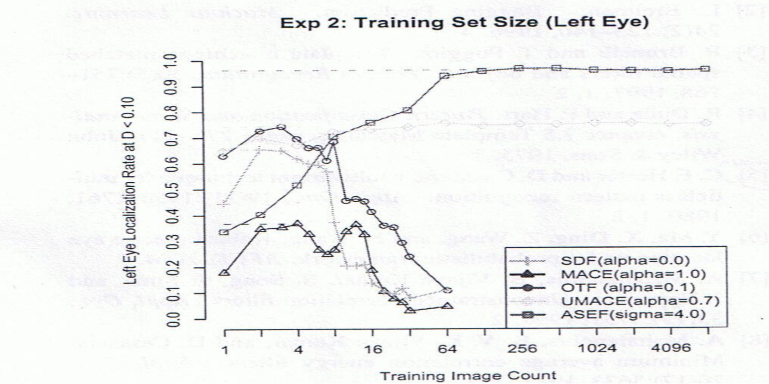
Experiment with Restriction

Search in region of expected location.



Experiment without Restrictions

Search entire image



My Experiment

- Used Convolution not Correlation
- No Restrictions
- Normalization: $log(v + 1)$
- Used 1000 images from BioID database

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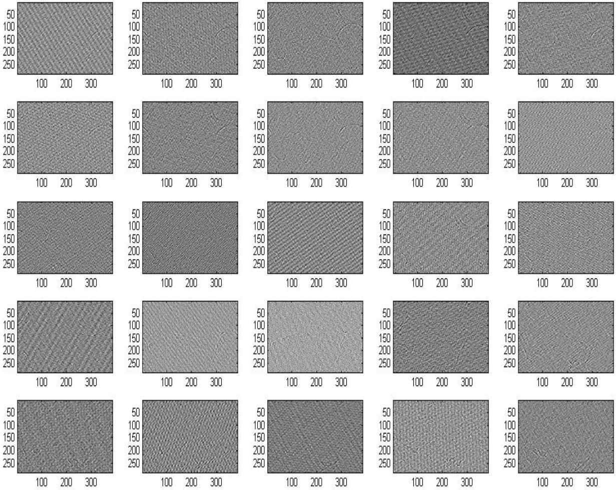
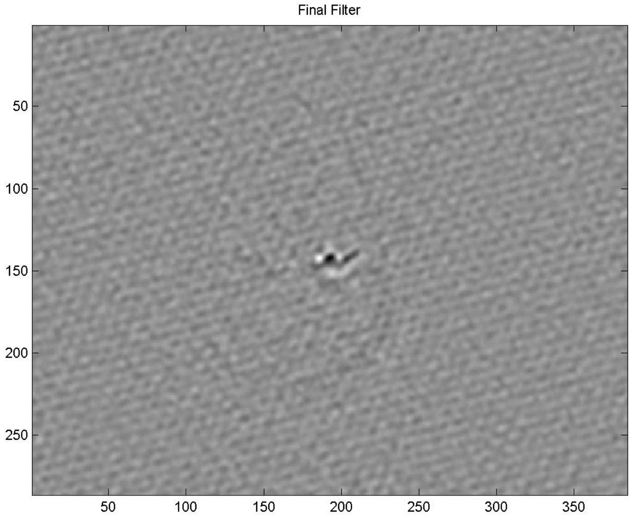
My Exact Filters

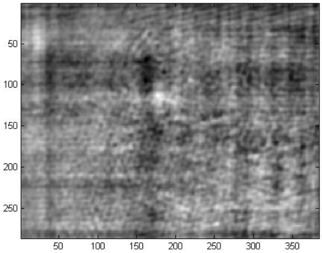


My Final Filter



Let's Try It!


50
100
150
200
250
50
100
150
200
250
300
350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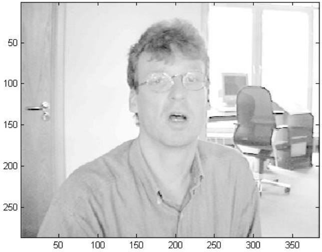
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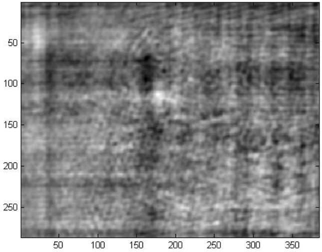
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100
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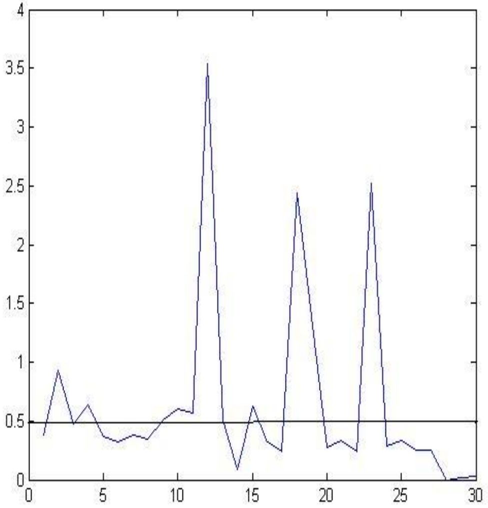
200
250
300
350

How Well Did It Work?

- $P_l = (177, 113)$
- $M_r = (177, 97)$
- $M_l = (219, 95)$
- $D = \frac{||P_l - M_l||}{||M_r - M_l||} = .3805$


4
3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30

Reference

Title:
Average of Synthetic Exact Filters

Authors:
David S. Bolme
Bruce A. Draper
J. Ross Beveridge