Average of Synthetic Exact Filters

Jose I. Pacheco

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

May 12, 2009
First step: Face Registration

How?

Find the eyes
First step: Face Registration

How?

Find the eyes
First step: Face Registration

How?

Find the eyes
Eye Localization

Goal:

Return pixel coordinates of eye center to within some tolerance.
Eye Localization

Goal:

Return pixel coordinates of eye center to within some tolerance
Problems

Two types of problems:

1. Prior Knowledge (e.g. location of face, known region of eye)

2. No Prior Knowledge
Problems

Two types of problems:

1. Prior Knowledge (e.g. location of face, known region of eye)

2. No Prior Knowledge
Convolution vs. Correlation

Convolution:

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

Correlation:

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

Convolution Theorem:

\[ \mathcal{F}(f \ast g) = \mathcal{F}(f) \cdot \mathcal{F}(g) \]

"Correlation" Theorem:

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

correlation filter

test image
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

\[ f_i(x, y) \ast h_i(x, y) = g_i(x, y) \]

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

\[
\begin{array}{ccc}
  f_1 & g_1 & h_1 \\
  f_2 & g_2 & h_2 \\
  f_3 & g_3 & h_3 \\
\end{array}
\]
Averaging

Now that we have $h_i$ let us calculate their average

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

(1)

Now that we have filter we can apply it.
But wait...why average?

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

\[
\frac{1}{N} \sum_{i=0}^{N} h_i
\]
Experimentation

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

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

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

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

- Left Eye
- Feret Database
- 1024 images for training set
- 1699 images for testing set
- Similarity transforms: rotations($\pm \frac{\pi}{6}$), scaling($1.0 \pm 0.1$), translations($\pm 4.0$)

Error $D = \frac{\|P_l - M_l\|}{\|M_l - M_r\|}$

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

Search in region of expected location.

![Graph showing training set size and left eye localization rate](image-url)
Experiment without Restrictions

Search entire image
My Experiment

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

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

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

- Used Convolution not Correlation
- No Restrictions
- Normalization: $\log(v + 1)$
- Used 1000 images from BioID database
My Exact Filters
My Final Filter
Let’s Try It!
Let’s Try It!
How Well Did It Work?

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

Title:
Average of Synthetic Exact Filters

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