Facing the Truth:
Using Color to Improve Facial Feature Extraction

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March 20, 2008
EE 362 – Applied Vision and Image Systems

Problem

- Problem: Failed Feature Extraction in OKAO
  - Tracking generally works on Caucasians, but…
  - …sometimes features are mislabeled
  - …or altogether lost/undetected
  - Particularly faulty for dark complexions


Objective

- Solution: Improving Feature Extraction using Color
  - More steady tracking
  - Fewer false features
  - Robust to perturbations: motion, blinking
  - Fewer empty frames
- Focus: African-American Faces
  - Subset of dark-skinned population
  - Three subjects with particularly low tracking accuracy
- Test Data from OKAO

Presentation Preview

- Prior Work in Face Tracking
  - Without color
  - With color
- Our Methods
  - Color edge boosting
  - Windowing
- Results and Discussion
- Conclusion → Possible Extensions


Prior Work in Face Detection & Recognition

- Classic segmentation using luminance, grayscale
  - Keypoint identification
  - Template matching
- Neural networks – train with database, adapt
- Feature-based registration [*Boehnen, Russ,* 2005]
- Localized edge detection
  - Threshold face first
  - Stronger threshold for eyes, nose


Prior Work in Use of Color Segmentation

- Feature-based approaches
  - Color edge detection using vector gradients

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$\nabla f \approx |G_x| + |G_y|$$

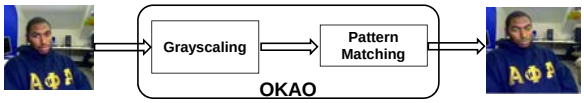
$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

- Image comparison methods
  - Pairwise feature matching (SIFT, SURF) with gargantuan training set
  - Joint Wavelet Coefficients from RGB channels [*Huang, Lai*, 2004]
- Skin region isolation → Template matching within skin region [*Campadelli, Lanzarotti, Lipori*, 2004]

- First Principal Component [*Dikbas, Arici, Altunbasak*, 2007]

Experimental Design

- Working with OKAO (*face* in Japanese)
  - Input: Color (RGB) frames of a centered face
  - System: Converts color frames to grayscale
  - System: Pattern matching for eyes and mouth
  - Output: Feature locations and statistics



- A Different Problem
  - Cannot simply detect color edges outside OKAO
  - Must *enhance* color images rather than grayscaling them

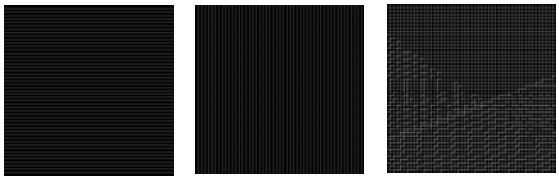
Benefits of Eigenimages (PCA)

- Where other methods fail, the principal component prevails:

4 × 4 Color Grid | **Color Laplacian** | **1st Eigenimage**

Benefits of Eigenimages (PCA)

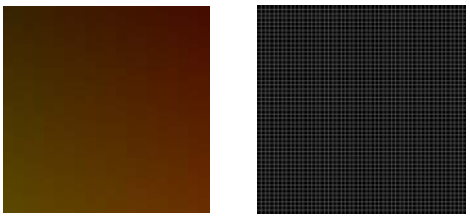
- Where other methods fail…



Grayscaling | **Luminance** | **Color Gradient**

Benefits of Eigenimages (PCA)

- The principal component usually succeeds:



Skin Color Grid | **1st Principal Component**

Using the Principal Component

- Convert RGB to eigenspace *[Dikbas, Arici, Altunbasak]*
- Three principal components

- How to use the principal eigenimage?
  - In place of the luminance channel?
  - Boosting the luminance channel?
  - Find edges, and boost luminance channel by edges?

Using the Principal Component

Replacing the Luminance Channel

Using the Principal Component

Boosting the Luminance Channel

Using the Principal Component

Edge-Boosting the Luminance Channel

Using the Color Gradient

- Color gradients

$$\nabla f_{xx} = \nabla R_x^2 + \nabla G_x^2 + \nabla B_x^2$$
$$\nabla f_{yy} = \nabla R_y^2 + \nabla G_y^2 + \nabla B_y^2$$
$$\nabla f_{xy} = \nabla R_x^T \nabla R_y + \nabla G_x^T \nabla G_y + \nabla B_x^T \nabla B_y$$

$$\theta = \frac{1}{2}\tan^{-1}\left(\frac{2\,\nabla f_{xy}}{\nabla f_{xx} - \nabla f_{yy}}\right)$$

$$|\nabla f| = \frac{1}{2}\left[\nabla f_{xx} + \nabla f_{yy} + \left(\nabla f_{xx} - \nabla f_{yy}\right)\cos 2\theta + 2\,\nabla f_{xy}\sin 2\theta\right]$$

- How to use the color edges?
  - In place of the luminance channel? (not feasible)
  - Boosting Y (CbCr)…RGB…(H)S(V)…(HS)I channels?
  - Find edges, and boost luminance channel by edges?

Using the Color Gradient

Edge-Boosting the Luminance Channel

Using the Color Gradient

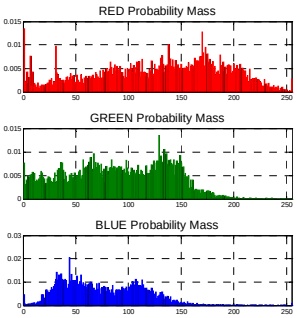
Edge-Boosting Each RGB Channel

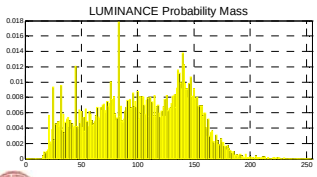
Using the Color Gradient

Boosting the Luminance Channel

Histogram Equalization

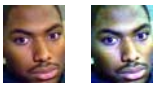
- Skin color histogram

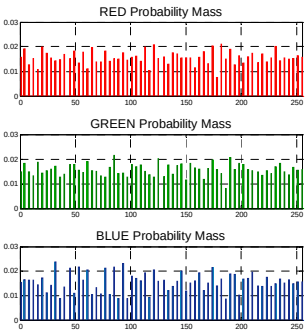


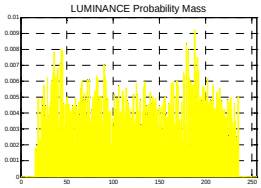


Histogram Equalization

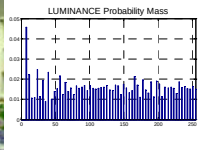
- Color (RGB) Equalization





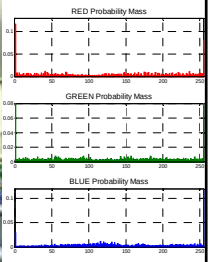


Equalizing RGB Histograms



Luminance Not Equalized

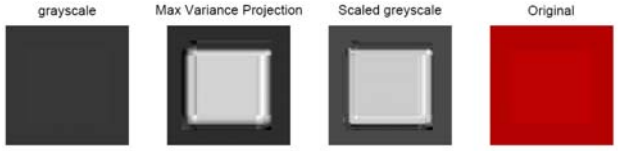
Equalizing the Luminance Histogram



Luminance Equalized

Other Scaling Methods

- Scaling grayscale image between 0 and 1
  - Luminance channel
- Maximum variance projection (~eigenimages)
  - Project color points onto axis of maximum variance
  - Enhances color contrast

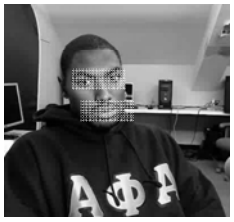


Other Scaling Methods

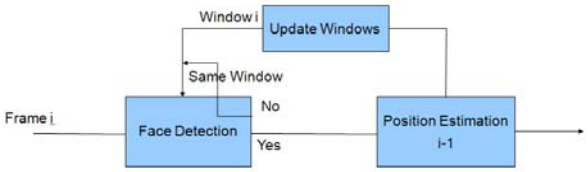
- Results
  - No noticeable improvement for “Scaled Grayscale”
  - Small improvement for maximum variance method
- **Reason**:
  Color contrast is local information, so considering the entire image “averages out” the facial contrast information

Windowing the Face

- Consider local contrast / color information
- Simulation of adaptive windowing



Windowing the Face



- Original video estimates position of mouth and eyes
- Estimate used to *adapt* window
  - Position at time *n* used to generate window at time (*n* + *1*)
  - Localizes relevant color or luminance values for maximal stretching

Windowing + Scaling

- Scaled Grayscale
- Maximal variance projection (~eigenimages)
- Maximal variance projection with emphasized luminance

Windowing + Scaling Results

- Few improvements using Scaled Grayscale
- Noticeable improvement for principal component
- Exceptional boost when luminance of first maximal variance projection is *scaled* and *truncated*

Results and Evaluation

- Average mean confidence – unreliable due to outliers
- Percentage of frames with higher confidence – resistant to outliers
- Visual evaluation

Average Mean Confidence

Subject	GrayScaleNW	GrayScaleSCNW
42	-0.04	-0.04
50	0	0
18	0	0

Subject	ColorGrad	ColorGrad Boosted	RGB Equalize	Eigenimages	Y Equalize
42	-0.22	-0.56	-0.5	-0.56	0.012
50	-0.5	-0.8	-0.5	-0.14	0
18	-0.1	-0.1	-0.52	-0.82	0

Subject	PCA NoWin	PCA LumScaleW1	PCA LumScaleW2	PCA LumScaleW3
42	-0.08	-0.37	-0.39	-0.43
50	0.01	0	0	-0.7
18	0	-0.28	-0.5	-0.7

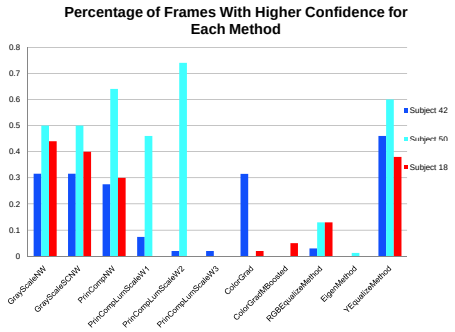
Percentage of Frames with Higher Confidence

Subject	GrayScaleNW	GrayScaleSCNW
42	0.316	0.316
50	0.5	0.5
18	0.44	0.4

Subject	ColorGrad	ColorGrad Boosted	RGB Equalize	Eigenimages	YEqualize
42	0.315	0	0.03	0	0.46
50	0	0	0.13	0.013	0.6
18	0.02	0.05	0.13	0	0.38

Subject	PCA NoWin	PCA LumScaleW1	PCA LumScaleW2	PCA LumScaleW3
42	0.2755	0.074	0.02	0.02
50	0.64	0.46	0.74	0
18	0.3	0	0	0

Graphical Results

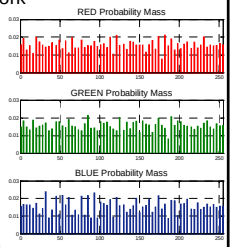


Visual Results

- Subject 50: Windowed Principal Component Luminance Scaled
- Subject 42: Color Gradient Edge Boosted
- Subject 42: Luminance Equalization

Presentation Review

- Applicability of previous work
- OKAO Challenges
  - Input: color image
- Color contrast boosting
  - Y-Channel Replacement
  - Luminance Boosting
  - Edge-Based Boosting
  - Equalization
- Advantages of Windowing
- Metrics for success → Windowing + PCA effective



Facing the Future

- More extensive testing
  - Other face trackers (we used OKAO)
  - More subjects or various shades (we used three)
  - Longer video sequences (we were limited by memory)
- Subjects with glasses
- Choosing the optimal method
  - Using image histogram as a selector
  - Predicting the effectiveness of a method before applying it
- Selective feature or color boosting
  - Not the generic "color edge" – select color range
  - Accentuate the mouth and eyes

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Acknowledgments

- Professor Brian Wandell
- Professor Joyce Farrell
- Research Assistant, Dr. Manu Parmar
- Research Assistant, Dr. Peter Catrysse
- Teaching Assistant, Christopher Anderson
- OMRON Research & Development (OKAO)
- Stanford Virtual Reality Lab