CAS CS 585
Image and Video Computing

0.5 Lecture by Margrit Betke

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Face Detection, Hierarchical Image Analysis, Motion Analysis by Image Differencing, Template Matching, SSD, NCC

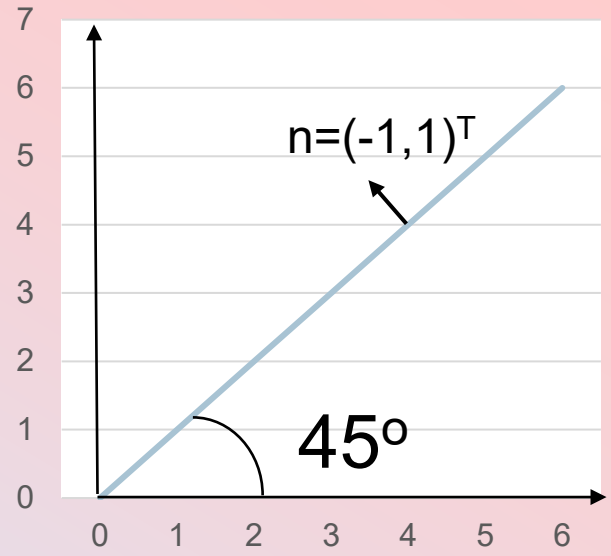
Class Poll:
Which line equation is wrong?

A. $y=mx+n$, where $m=1$, $n=0$

B. $(-1,1)^T \mathbf{x} - g = 0$, where $g=\sqrt{2}$

C. $-x \sin \alpha + y \cos \alpha = 0$, where $\alpha = 45$ degrees

D. $(-\sin \pi/4, \cos \pi/4)^T \mathbf{x} = 0$



Finding the Head and its Movement by Detecting Pixels with Skin Color

Hope:

Largest skin color "blob" is face.

Fewer false positive skin pixels in background, e.g., wooden door.

Finding the Head and its Movement by Detecting Pixels with Skin Color

(a) Input (b) Color

Common Trick in Computer Vision:

Use

"image pyramid" = input image at difference scale.

Here: 6 levels, reduction in x, y by ¼ (other schemes possible)

Then process result pyramid. Why?

Finding Movement by Detecting Pixels with Brightness Changes

(a) Input

(c) Motion

- *DifferenceImage(x,y,t) = Image(x,y,t)-Image(x,y,t-1)*
- *Or*

DifferenceImage(x,y,t) = Image(x,y,t)-Image(x,y,t-k)

where k > 1, e.g., 10

- *Or*

DifferenceImage(x,y,t) = |Image(x,y,t)-Image(x,y,t-k)|

Why absolute value?

Finding the Face and its Movement by Locating the Best Match of a Face Template

(a) Input

Better matches shown brighter

Best match: Blue pixel

Finding the Face and its Movement by Locating the Best Match of a Face Template

Computer Science

Use Jingbin's face as a template

Visualization
of Match Values

How can we compute a match?

Template Matching with Sum-Squared Difference (SSD)

Computer Science

- *Scene subimage s, template image m*
- *same size images = n pixels*
- s_i *= ith pixel in subimage of scene*
- m_i *= ith pixel in template image m*

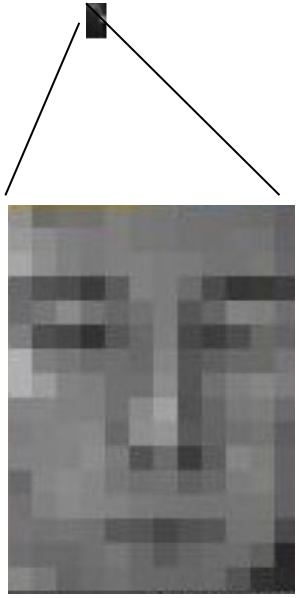
- $SSD = \Sigma\_(i=1 \text{ to } n) \quad (s_i - m_i)^2$

- *Template matching =* exhaustive search algorithm *for position of scene subimage that best matches the template (where SSD is smallest)*

Finding the Face and its Movement by Locating the Best Match of a Face Template

Computer Science

Used average face as a template



Visualization of Match Values

Normalized Correlation Coefficient (NCC)

Paired pixels in image X and Image Y:

$$\{(x_1, y_1), \ldots, (x_n, y_n)\}$$

Definition of NNC:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

where the mean for the image X pixel values is

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

The mean for Y is defined similarly.

The NCC is also called “Pearson coefficient.” Pearson was not the inventor. He is known for eugenics and scientific racism, so we will not use his name to describe the NCC in CS 585.

Template Matching via with Normalized Correlation

- Scene subimage *s*, template *image m*
- *Normalized correlation coefficient*

  $r = 1/n \, \Sigma_i ((s_i - mean(s)) * (m_i - mean(m)) / (\sigma_s \, \sigma_m))$ *where*

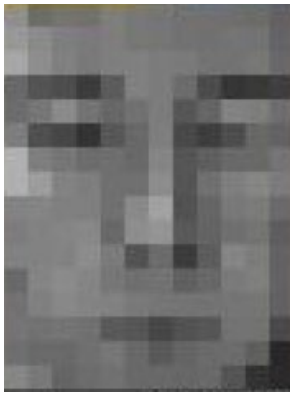
  s_i and m_i are respective brightness values of the *i*th pixel

  mean(m) and σ_m are mean and standard deviation of all pixels in the template

  mean(s) and σ_s are mean and standard deviation of all pixels in the subimage of the scene
- Template matching = exhaustive search for position of subimage that produces highest *r*
- *r* can be between -1 and 1

Finding the Face and its Movement by Locating the Best Match of a Face Template

Used average face as a template



Visualization of Normalized Correlation Coefficient Match Values

Finding the Face with Template Matching & the Normalized Correlation Coefficient

(a) Input

(d) Correlation

Multi-Resolution Matching

Computer Science

Normalized correlation coefficient over multi-resolution search space:

$$r = \frac{1}{n} \frac{\Sigma_i (s_i - mean(s))\,(m_i - mean(m))}{(\sigma_s\,\sigma_m)}$$

←Template matched over all resolutions →

Finding the Face and its Movement by Locating the Best Match of a Face Template

(a) Input

You can apply template matching to a small version of your input image and use that search result to start searching for a match in the 2nd smallest images. Repeat until the original size is processed.

(d) Correlation

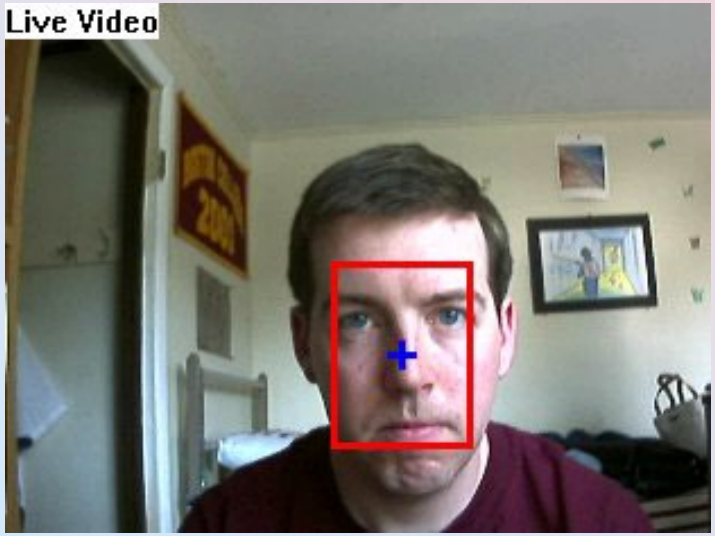
Multi-scale Pyramids

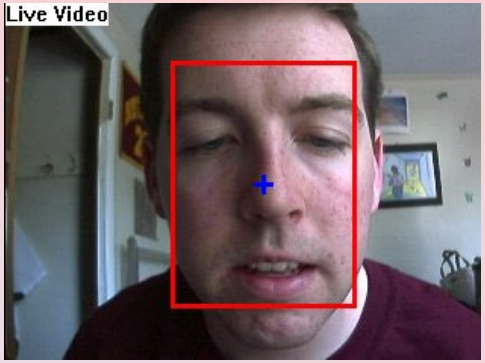
Combine the results of color and motion detection to mask the regions of interest for correlation-based template matching

(a) Input (b) Color (c) Motion (low-pass filter (d) Correlation (e) Masked Correlation

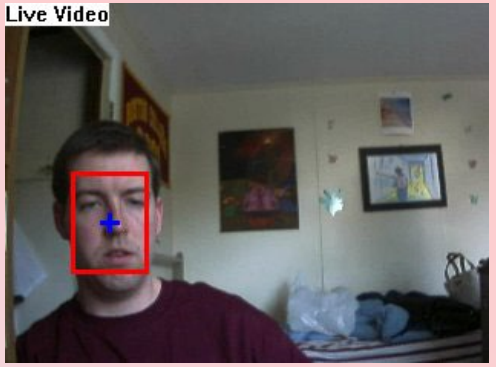
Face Detection

Data Variability





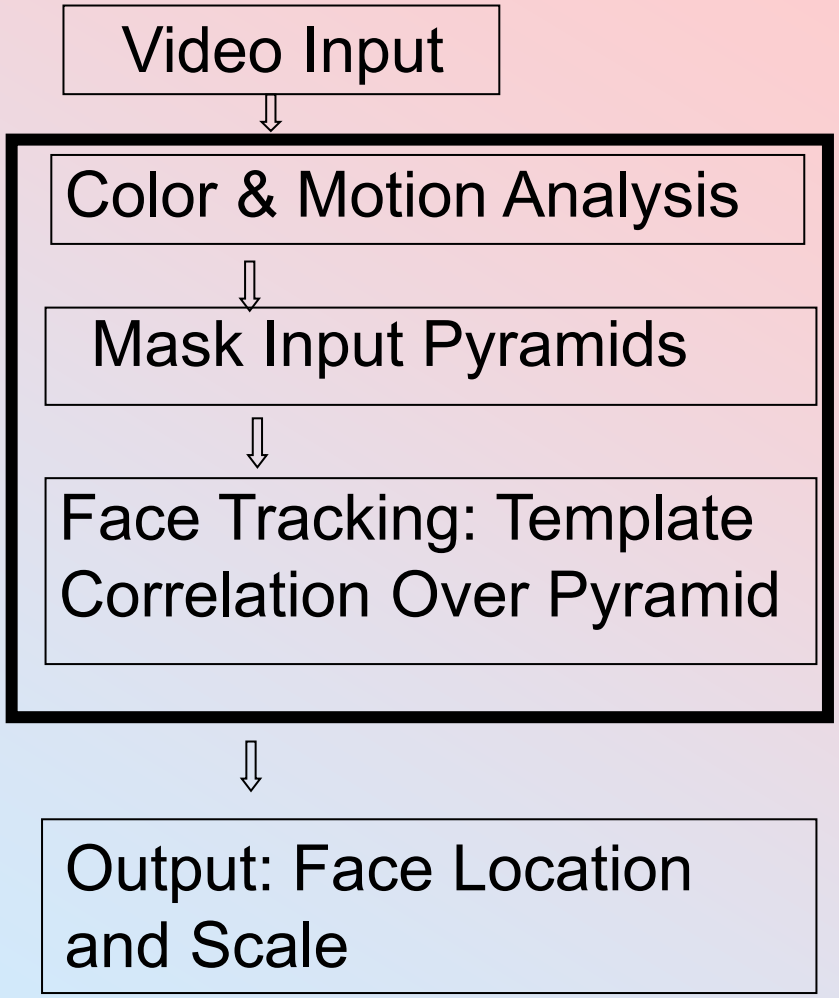
Large Face



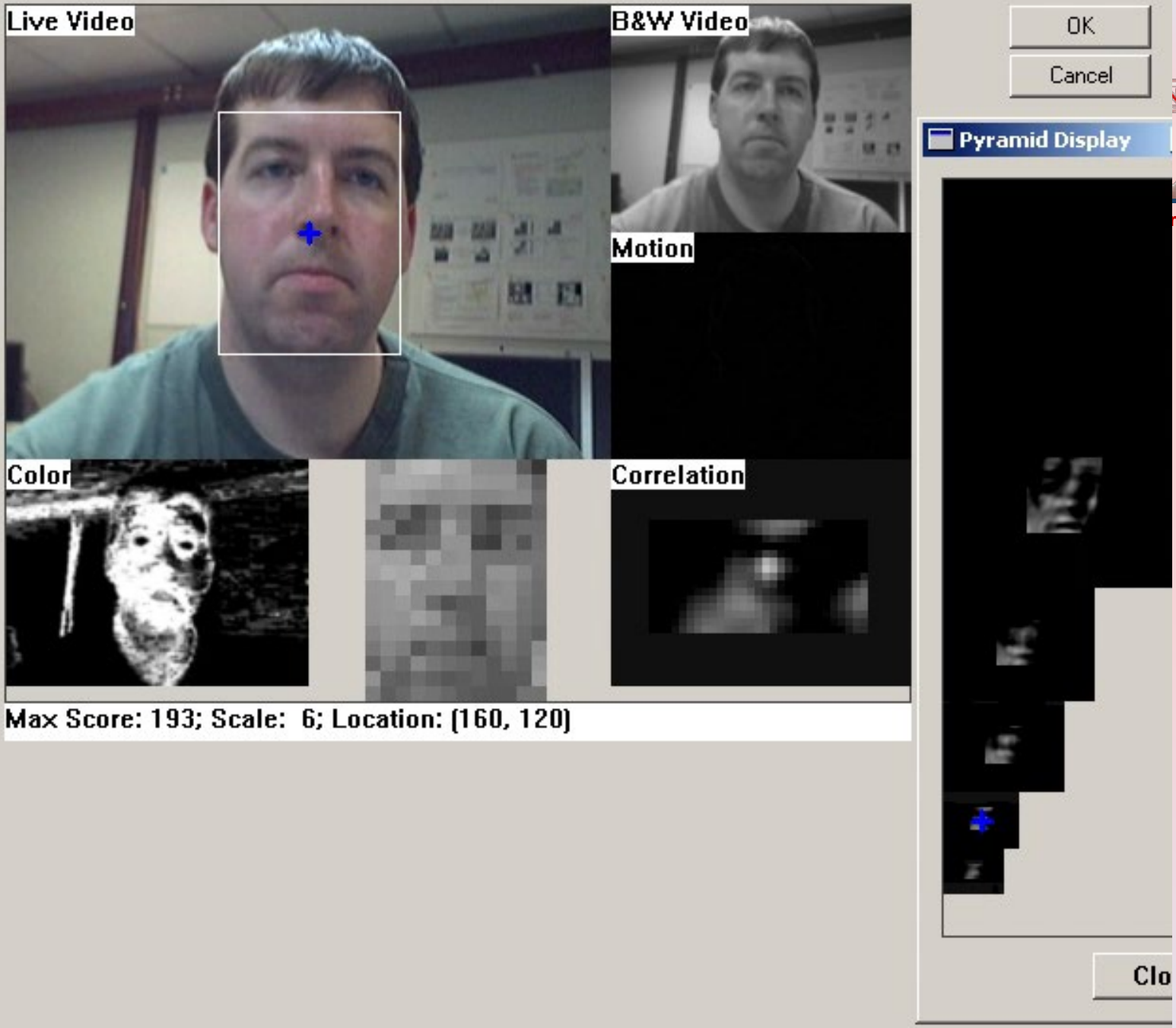
Small Face

Shadows
Cluttered background

Algorithm: Multi-scale Face Detection



Face Detection Interface


Live Video
B&W Video
OK
Cancel
Pyramid Display
Motion
Color
Correlation
Max Score: 193; Scale: 6; Location: (160, 120)
Clo

Learning Objectives

Computer Science

Can explain and apply to image analysis problems:

- Detection by Color Analysis
- Hierarchical Image Analysis
- Motion Analysis by Image Differencing
- Sum-squared Difference (SSD)
- Normalized Correlation Coefficient (NCC)
- Template Matching with SSD or NCC