Topics

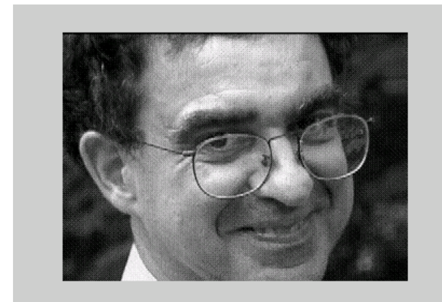
Part I
- Fourier Transform
- Windowed Fourier Transform
- Wavelets

Part II
- Principal Component Analysis
- Independent Component Analysis

Fourier Transform $\hat{f}(\omega_x, \omega_y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)e^{-j2\pi(\omega_x x + \omega_y y)}dxdy$

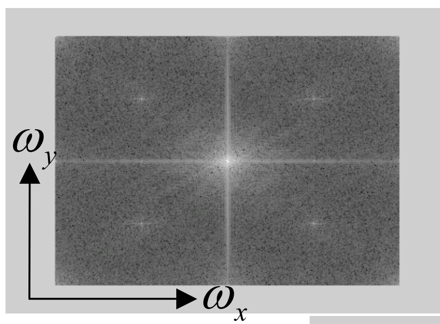
Image

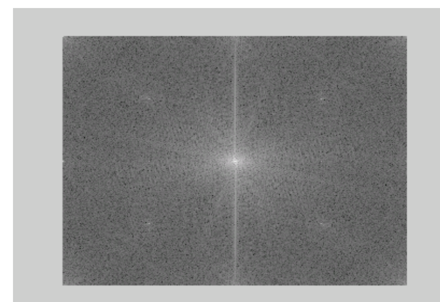
(A)



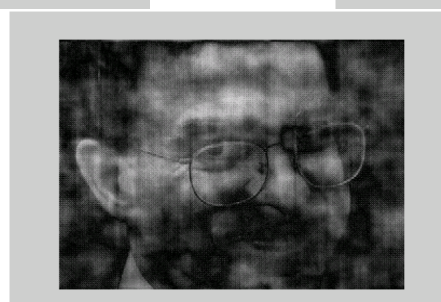
(B)

Spectrum





Phase carries Information



Amplitude of (A) & Phase of (B)

Template Matching

$$c(x) = \int_{-\infty}^{\infty} f(x')g(x'-x)dx' \quad h(x) = g(-x)$$

$$c(x) = \int_{-\infty}^{\infty} f(x')h(x-x')dx' \quad \hat{c}(\omega) = \hat{f}(\omega)\hat{h}(\omega)$$

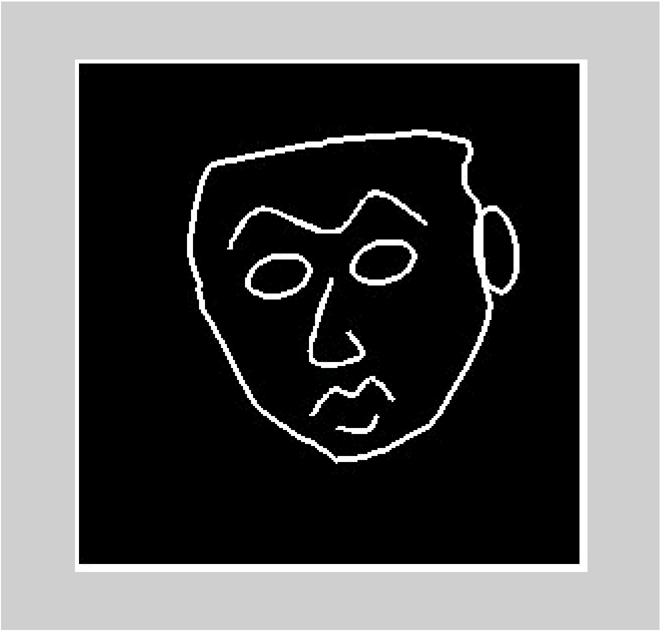
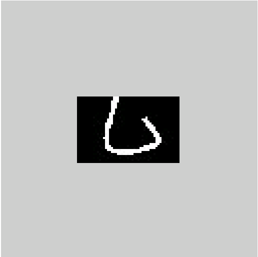
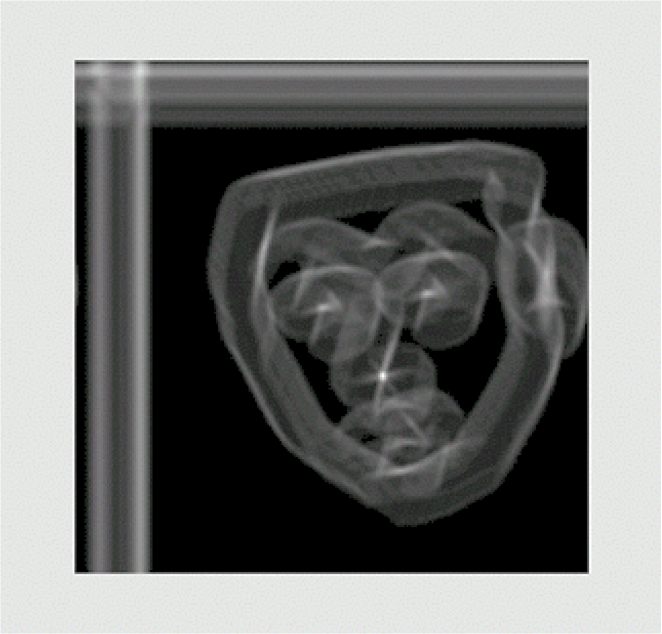


Image f



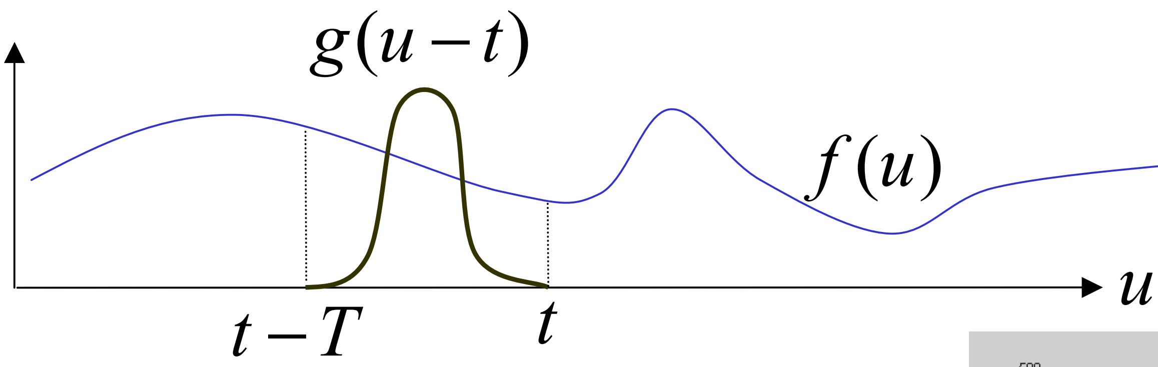
Template g

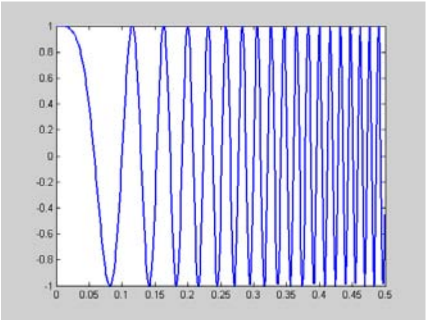


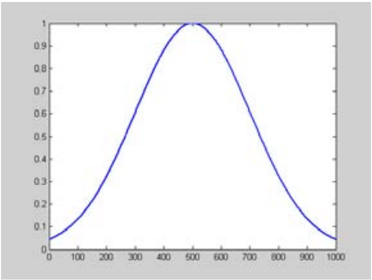
Result c

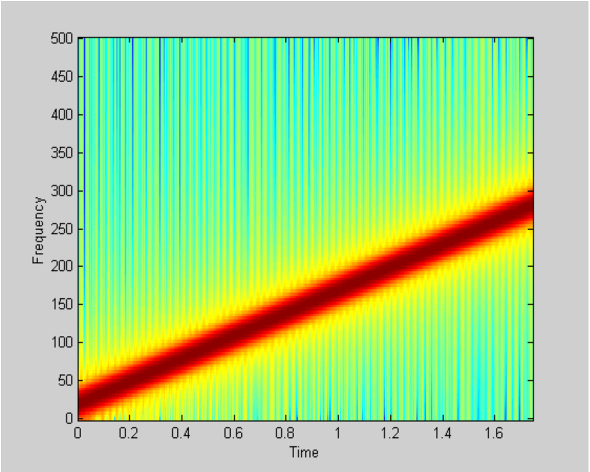
Windowed Fourier Transform

$$\tilde{f}(\omega,t)=\int_{-\infty}^{\infty} f(u)g(u-t)e^{-j2\pi\omega u}du$$









$f(t)=\cos(\pi t^2),\ \omega_{\text{inst}}=t$ $\qquad g(t)$ $\qquad \tilde{f}(\omega,t)$

Wavelet Transform

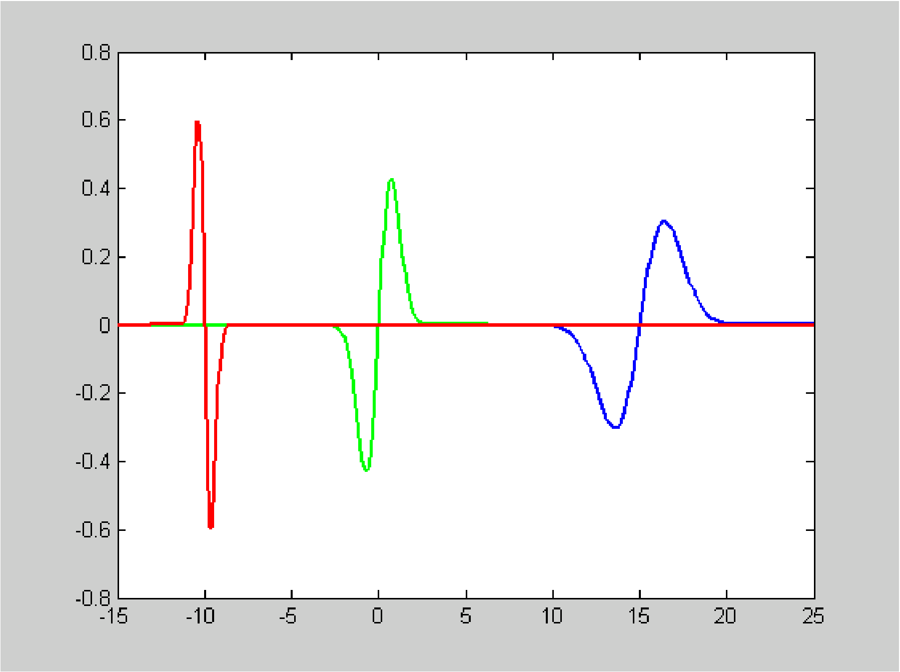
$$T(s,t) = \int_{-\infty}^{\infty} f(u)\overline{\psi}_{s,t}(u)\,du \qquad \psi_{s,t}(u) = \frac{1}{s^p}\psi\left(\frac{u-t}{s}\right)$$

$$\psi(u) = ue^{-u^2}$$

$\psi_{-0.5,-10}$ red

$\psi_{-1,0}$ green

$\psi_{2,15}$ blue



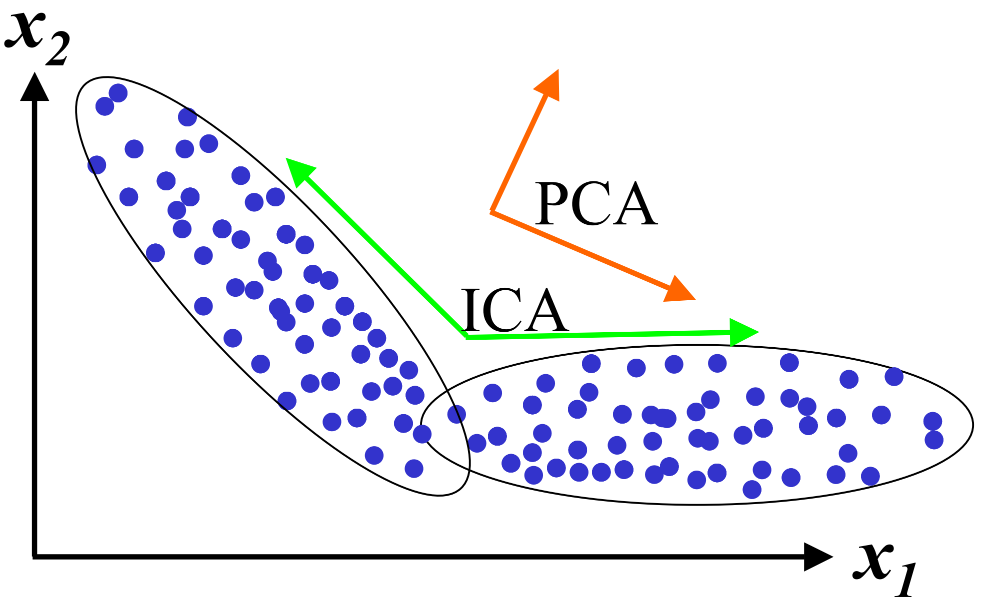
Haar Wavelets (Matlab Toolbox)

Screenshot from Matlab Toolbox removed due to copyright reasons.

Principal and Independent Component Analysis

PCA:
- Decorrelated
- Orthogonal

ICA:
- Statistically Independent



PCA

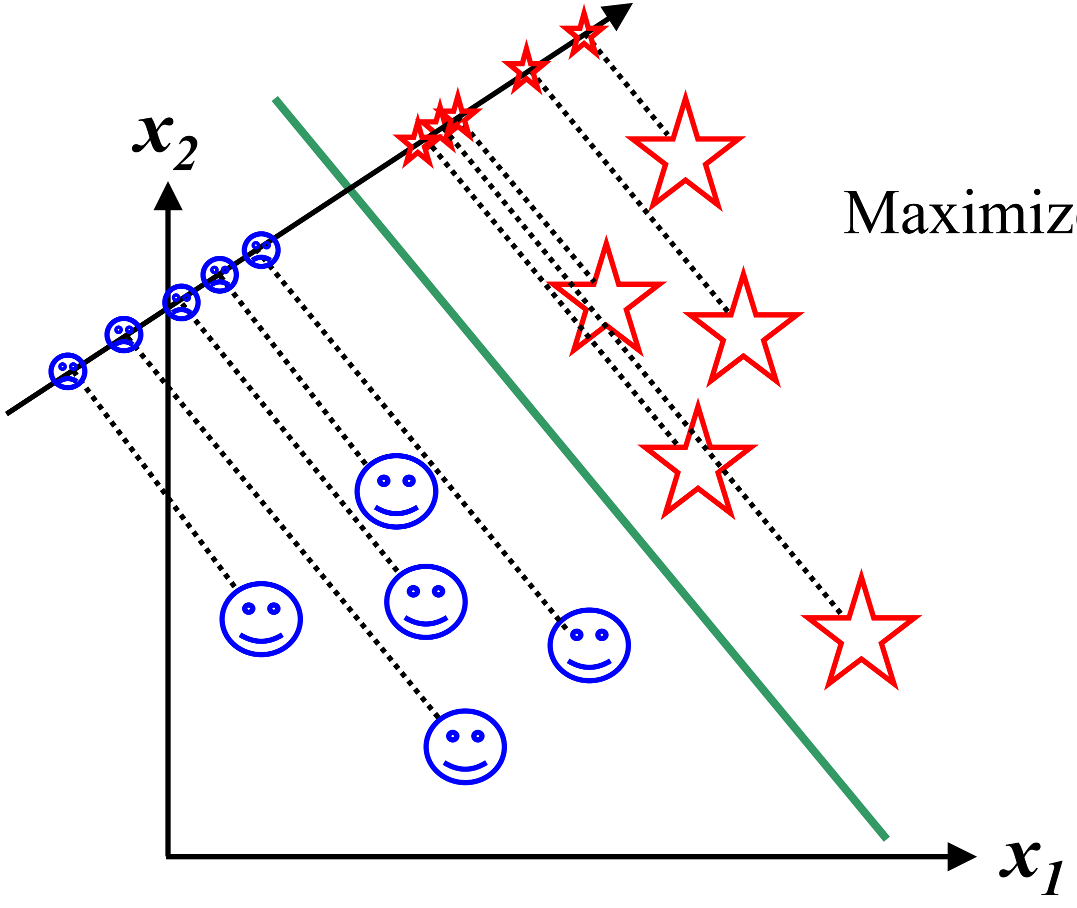
ICA

Image removed due to copyright considerations. See Figure 1 in:
Baek, Kyungim, et. al. "PCA vs. ICA: A comparison on the FERET data set." International Conference of Computer Vision, Pattern Recognition, and Image Processing, in conjunction with the 6th JCIS. Durham, NC, March 8-14 2002, June 2001.

Topics

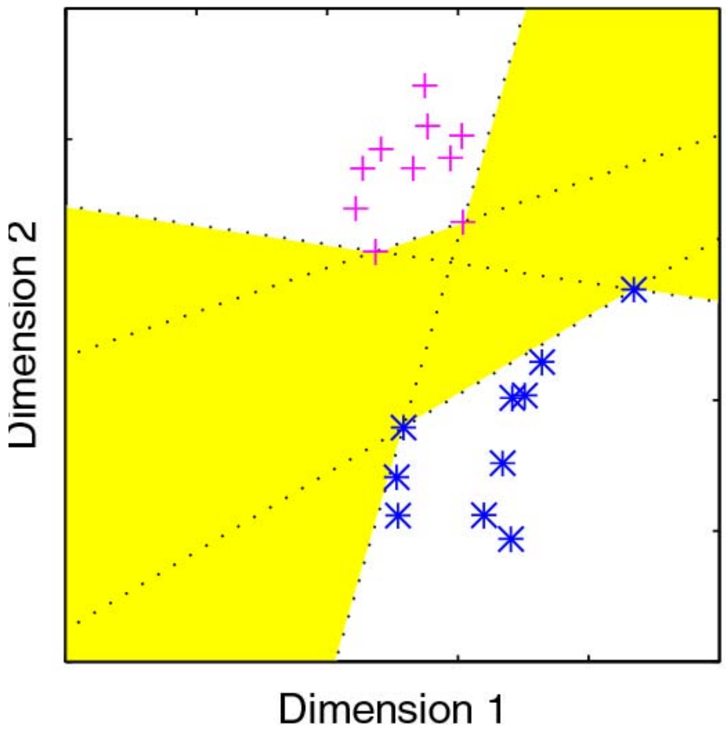
Fisher Discriminant Analysis (FDA)
•Support Vector Machines (SVM)

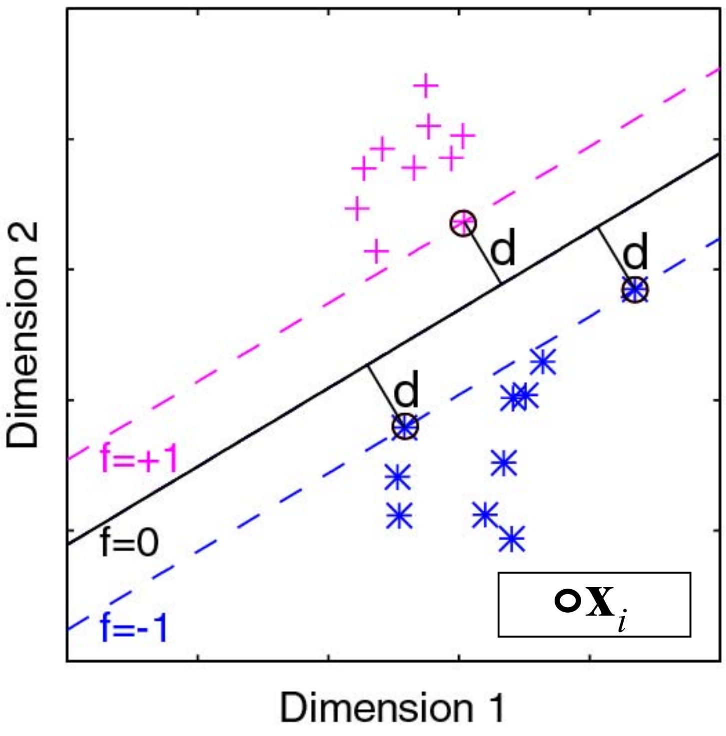
Fisher Discriminant Analysis



Maximize $\dfrac{(m_1 - m_2)^2}{\sigma_1^{\,2} + \sigma_2^{\,2}}$

Linear Support Vector Machines

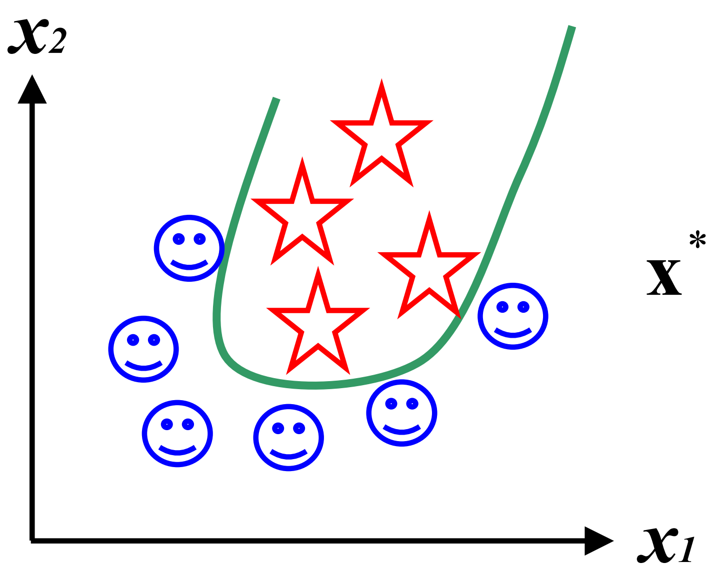




Maximize margin d

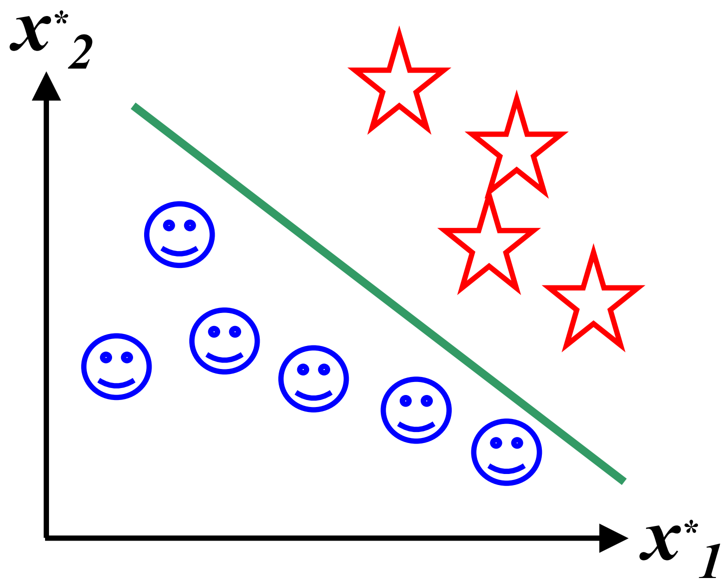
$$f(\mathbf{x}) = sign\left(\sum_{i=1}^{N} y_i \alpha_i \mathbf{x}_i \cdot \mathbf{x} - b\right)$$

Non-linear Support Vector Machines



Input Space

$$\mathbf{x}^* = \Phi(\mathbf{x})$$



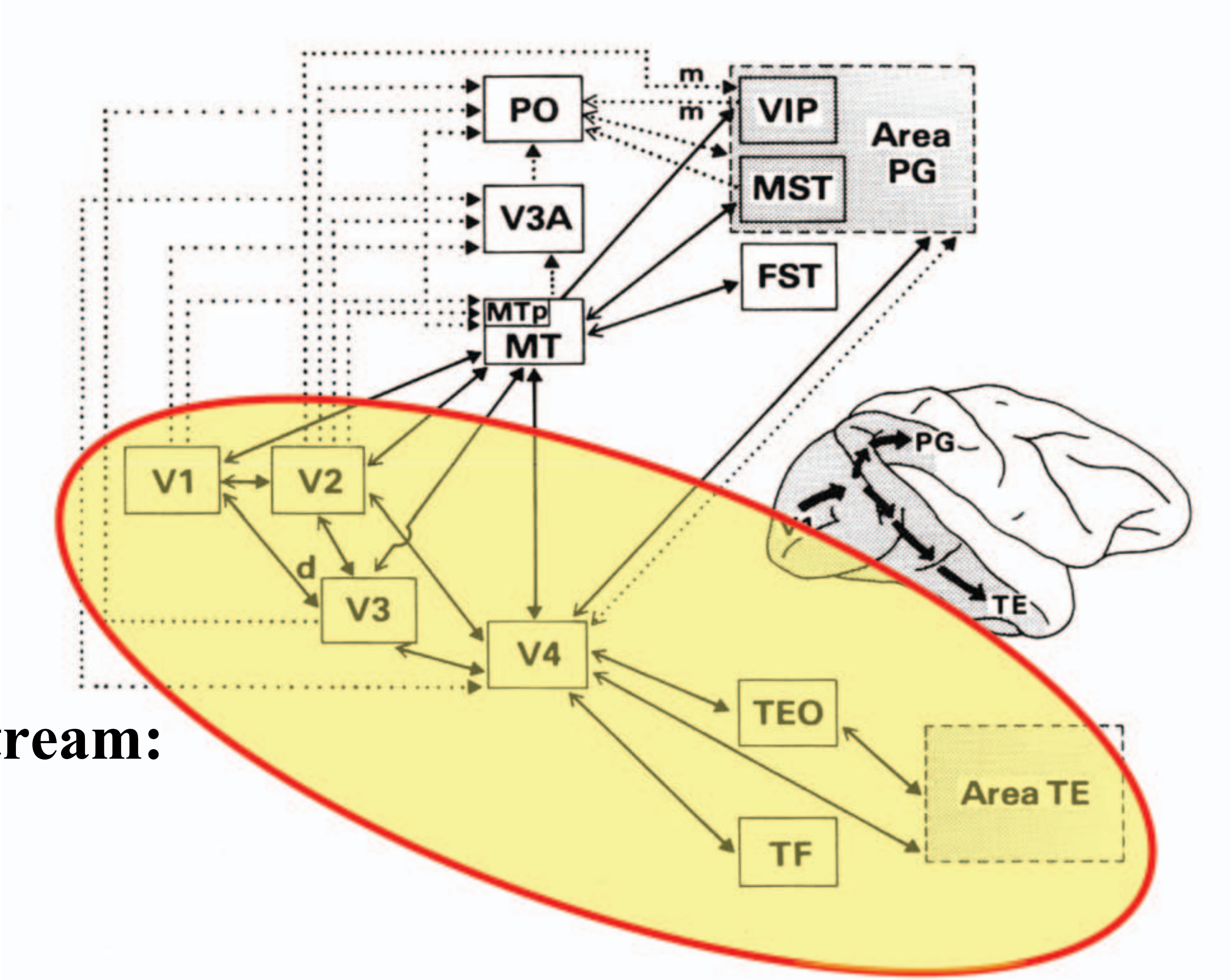
Feature Space

$$f(\mathbf{x}) = sign\left(\sum_{i=1}^{N} y_i \alpha_i K(\mathbf{x}_i, \mathbf{x}) - b\right), \quad K(\mathbf{x}_i, \mathbf{x}) = \Phi(\mathbf{x}_i)\Phi(\mathbf{x})$$

Topics

- Visual Cortex
- Hierarchical Processing
- Scale Invariance
- MAX Model for Object Recognition

The Visual System Simplified



Ventral stream: What?

Figure 1 in: Ungerleider, L., et. al. "A neural system for human visual working memory." *Proceedings of the National Academy of Sciences* 95 (February 1998): 883-890. Copyright 1998 National Academy of Sciences, U.S.A.

Vision—Biological Object Recognition

From Small and Simple to Big and Complex

Simple cells:
Orientation of bars

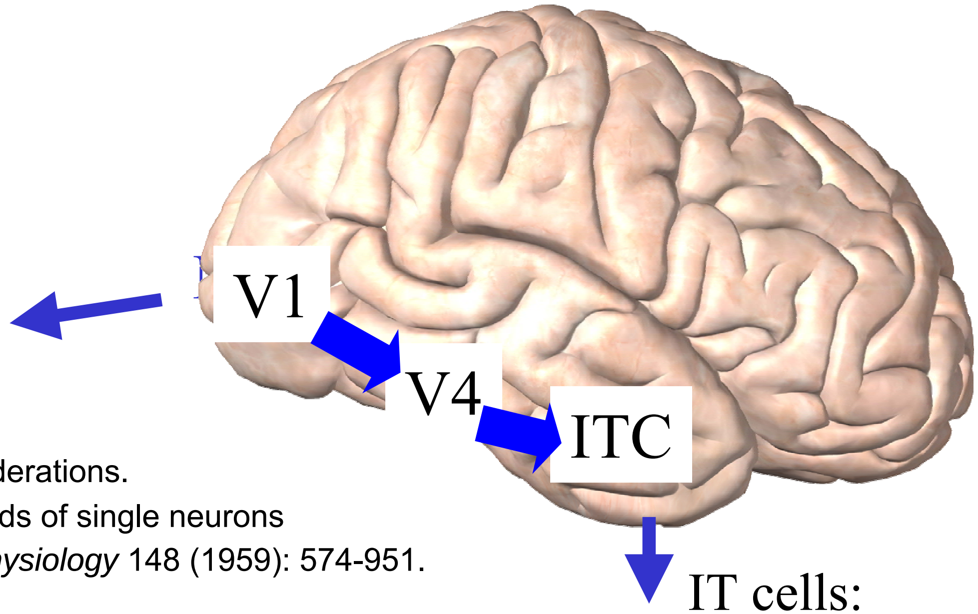


Image removed due to copyright considerations.
See: Hubel, and Weisel. "Receptive fields of single neurons in the cat's striate cortex." *Journal of Physiology* 148 (1959): 574-951.

IT cells:
Object specific

Hubel & Wiesel, 1959

Image removed due to copyright considerations. See:
Ungerleider, and Haxby. "'What' and 'where' in the human brain." *Current Opinion in Neurobiology* 4, no. 2 (1994): 157-165.

modified from Ungerleider and Haxby, 1994

Hierarchical Processing: From Simple to Complex Features

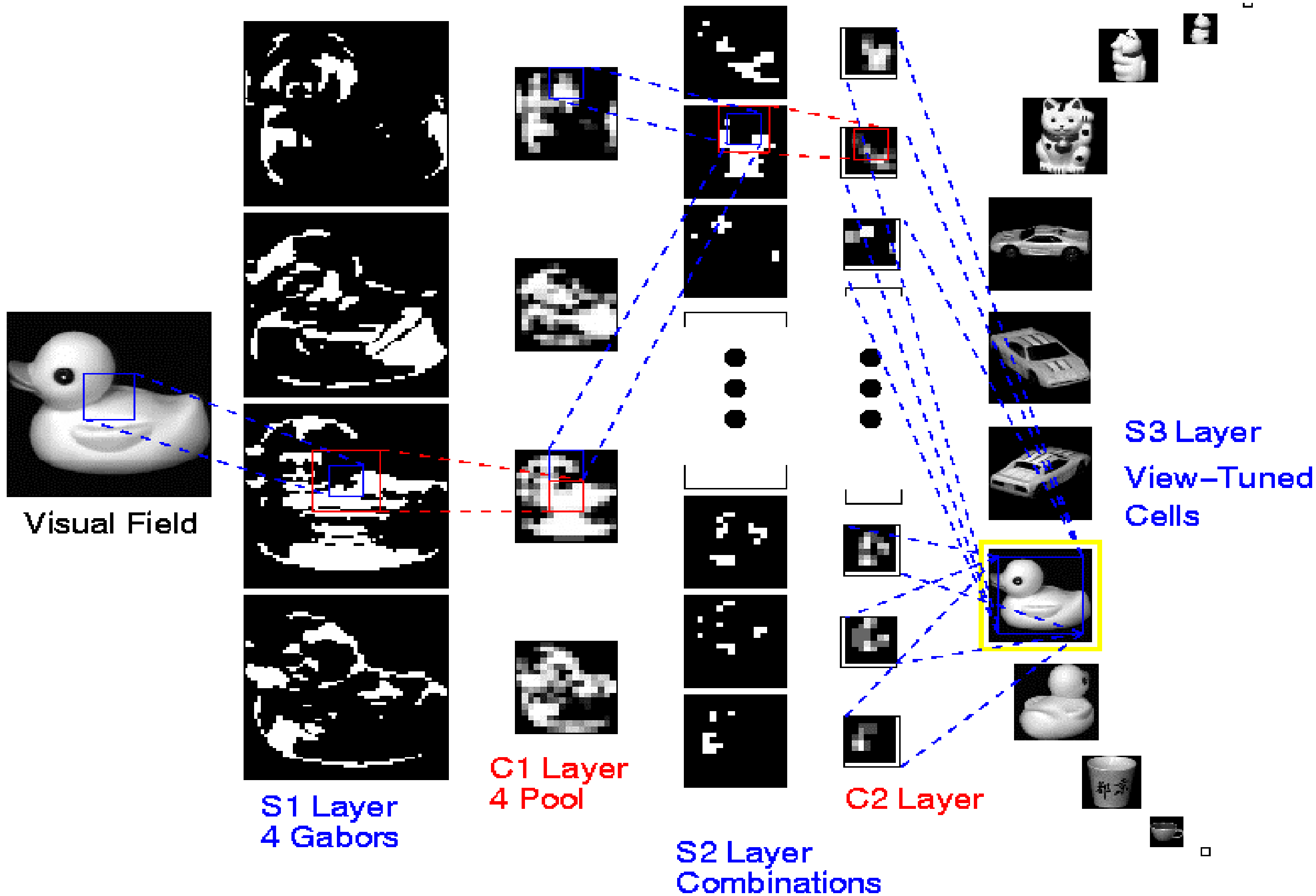


Figure 1 in: Wersing, H., and E. Korner. "Learning Optimized Features for Hierarchical Models of Invariant Object Recognition." *Neural Computation* 15, no. 7 (2003): 1559-1558. MIT Press Journals. Courtesy of MIT Press Journals. Used with permission.

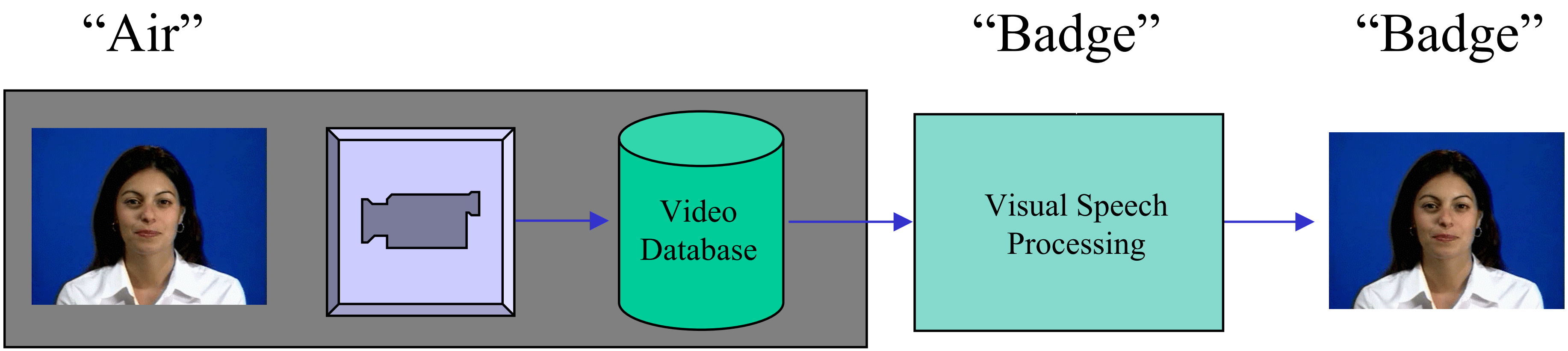
Topics

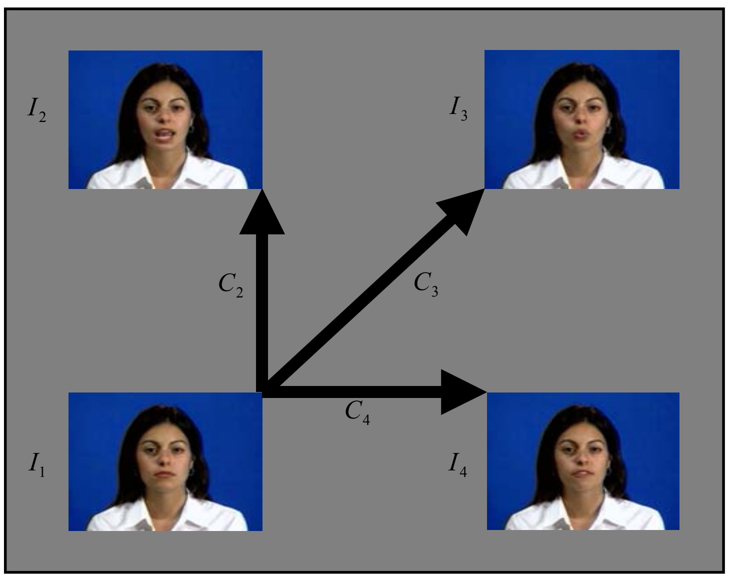
- 2D MMs of facical components
- 2D MMs for facial animation

- 3D MMs of faces
- Modifying faces in the MM space

Applications—Morphable Models

2D Morphable Models for Facial Animation



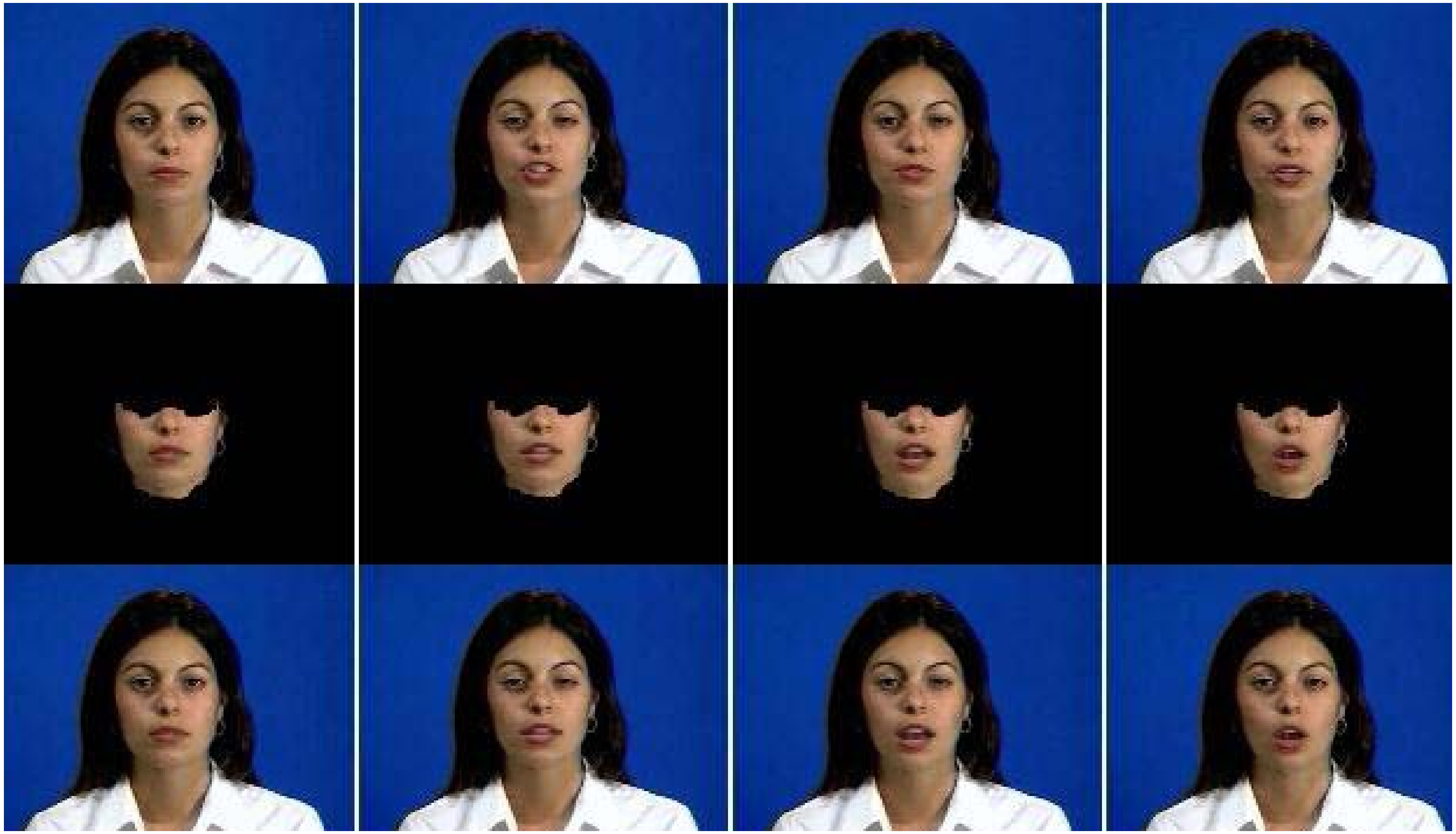


Building a 2D MM

- Video realism
- Machine learning

From Figure 1 in: Ezzat, Geiger, and Poggio. "Trainable Videorealistic Speech Animation." Proceedings of SIGGRAPH 2002, San Antonio, TX. Courtesy of authors. Used with permission.

2D Morphable Models for Facial Animation



From Figure 10 in: Ezzat, Geiger, and Poggio. "Trainable Videorealistic Speech Animation." Proceedings of SIGGRAPH 2002, San Antonio, TX. Courtesy of authors. Used with permission.

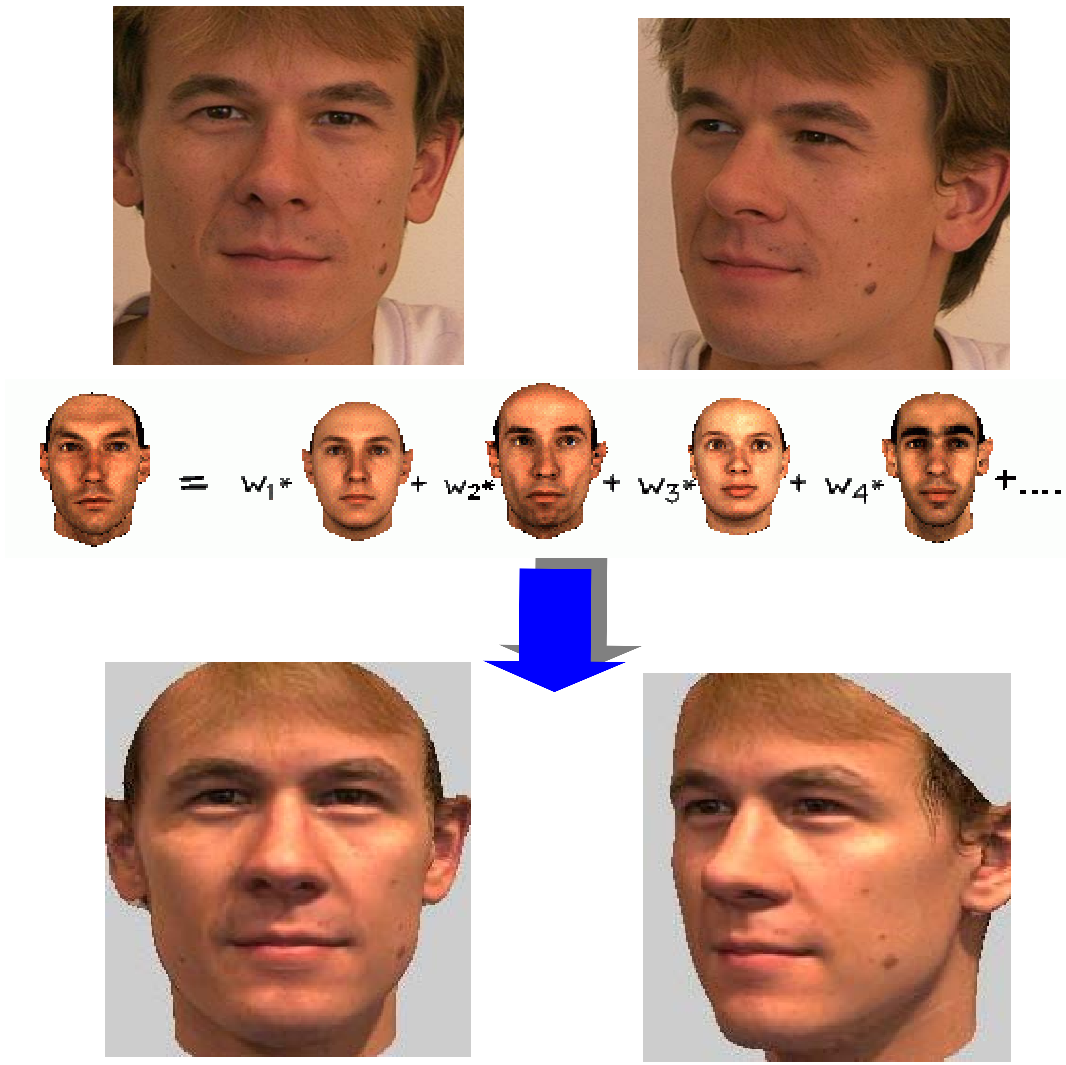
Applications—Morphable Models

Generating 3D Face Models with MM

Face Images

Morphing Space

3D Face Model



Courtesy of Maxmillian Riesen-Huber. Used with permission.

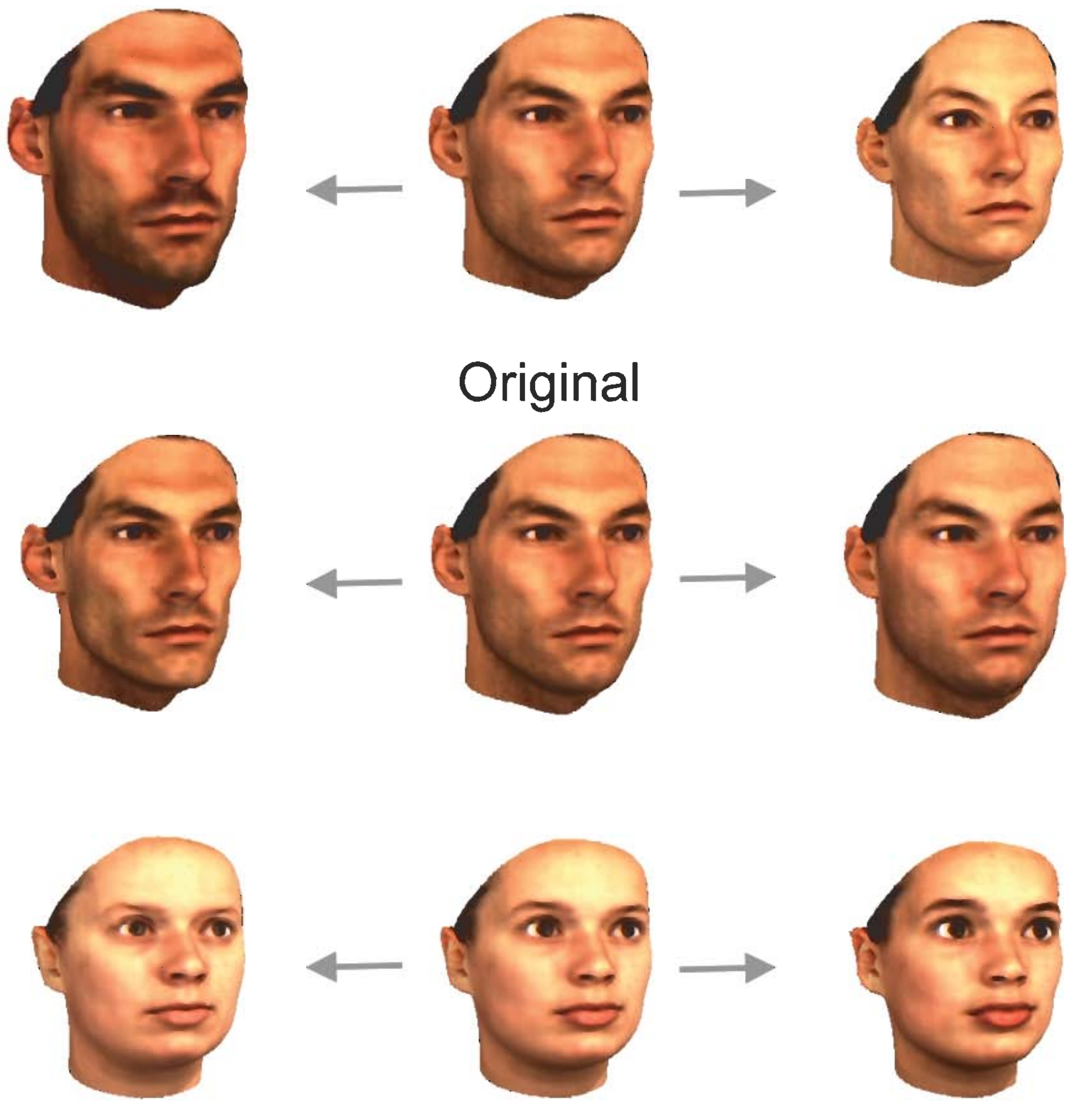
Modifying Faces in the MM Space

Figures removed due to copyright considerations. Please see:

Figures from Vetter, T., and V. Blanz. "A Morphable Model for the Synthesis of 3D Faces." *Proceedings of SIGGRAPH* (1999).

Novel Images

Morphing Facial Attributes



From: Vetter, T., and V. Blanz. "A Morphable Model for the Synthesis of 3D Faces." *Proceedings of SIGGRAPH* (1999).
Courtesy of T. Vetter and V. Blanz. Used with Permission.

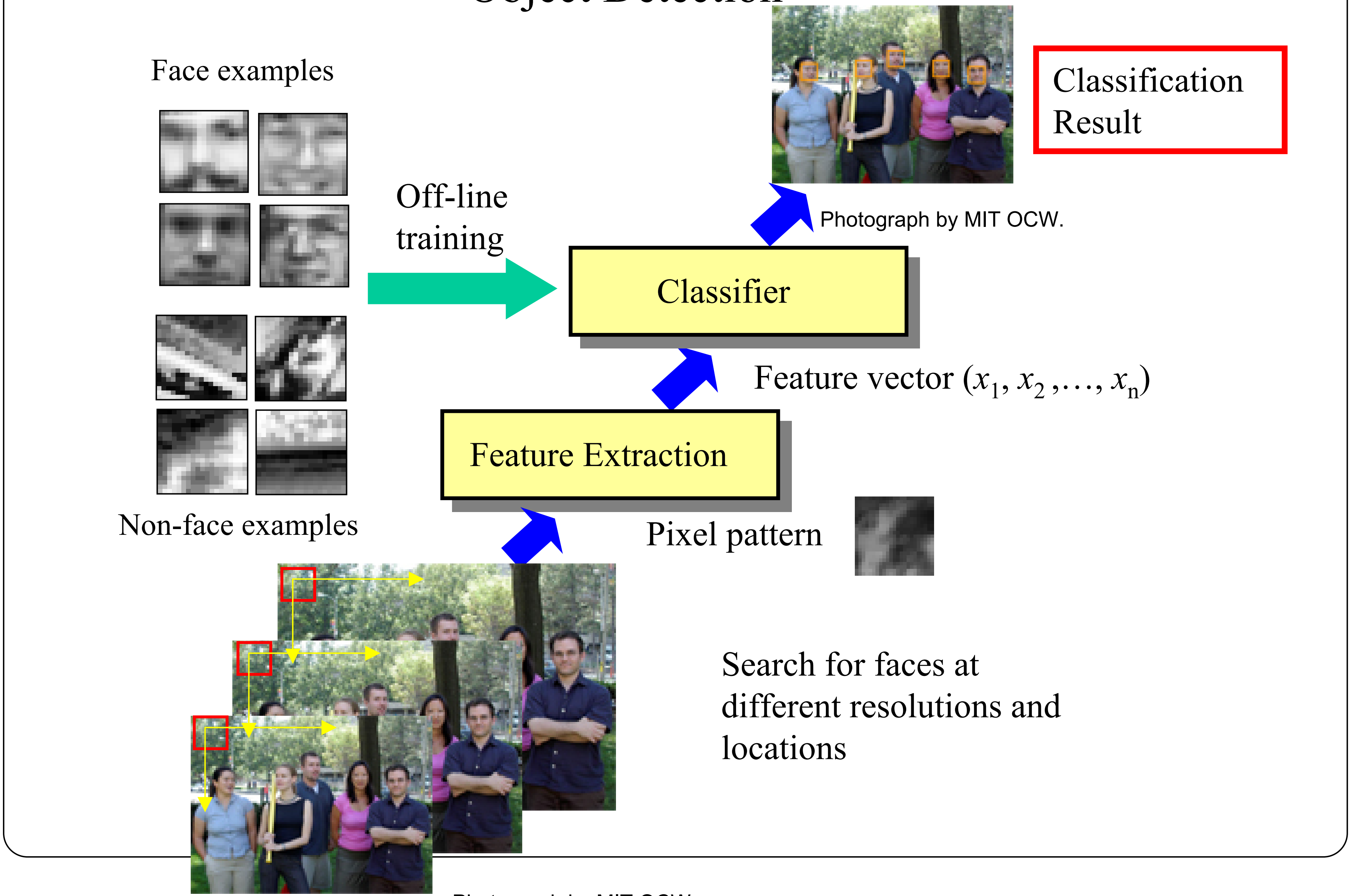
Applications—Object Detection & Recognition

Topics

- Face detection & recognition
- Pedestrian detection
- Feature extraction
- Classification

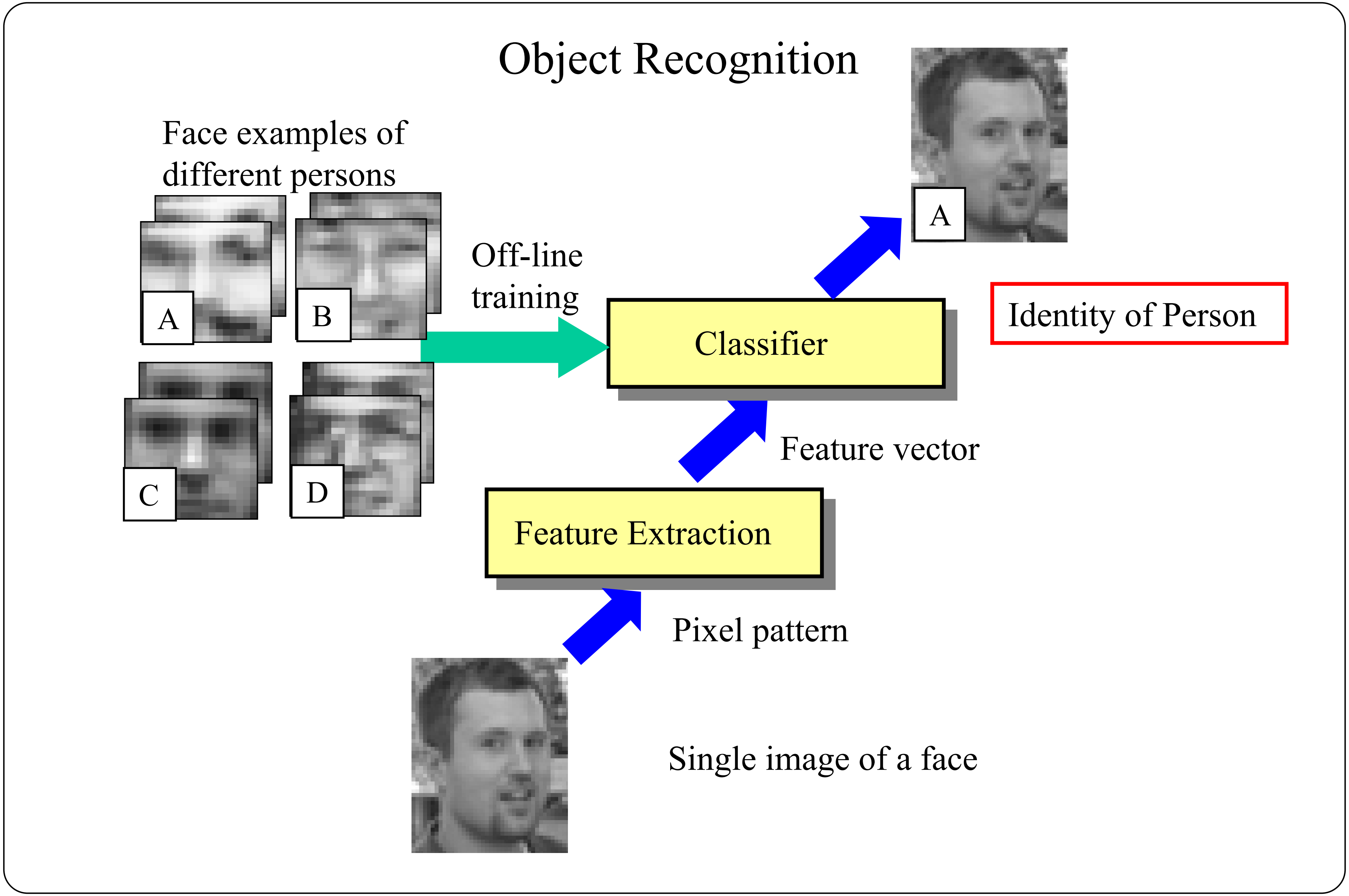
Applications—Object Detection & Recognition

Object Detection



Photograph by MIT OCW.

Applications—Object Detection & Recognition



Applications—Object Detection & Recognition

Face and Pedestrian Detection