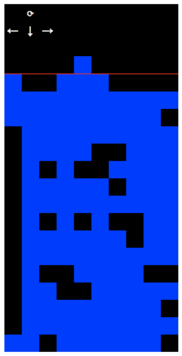


http://qntm.org/files/hatetris/hatetris.html

Computer Vision

CS151
David Kauchak

some slides modified from slides obtained from Zach Dodds

Admin

- Schedule for the rest of the quarter
  - Wed. class
  - 11/29 status report #2
  - 12/1 Exam #2 (a week from Wednesday!)
  - After exam: focus will be your projects
- No more TA office hours (unless needed?)

Tons of other NLP problems

- Information extraction
  - find entities in text
  - find how they relate to each other
- Information retrieval (search)
- Speech recognition
- Speech generation
- Dialogue/conversational agents
  - http://www.chatbots.org/us
  - http://www.geekcavecreations.com/pChat/
- Summarization
- Text simplification/compression

Tons of other NLP problems

- Language recognition (play with Google translate)
- Word sense disambiguation
- Text understanding
- Question answering
- Text coherence
  - Coreference resolution
- Text segmentation
- Document classification
- Document clustering
- …

Some resources

- Books
  - Speech and Language Processing. 2009. Jurafsky and Martin.
  - Foundations of Statistical Natural Language Processing. 1999. Manning and Schutze.
- Software
  - Stanford has a good tool collection:
    - http://nlp.stanford.edu/software/index.shtml
  - Berkeley has a few:
    - http://nlp.cs.berkeley.edu/Main.html#Software
  - Natural Language Toolkit (NLTK)
    - python
    - http://www.nltk.org/

Every picture tells a story…

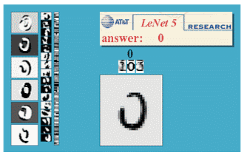
What is going on in this picture?

How did you figure it out?

Computer Vision

- the goal of computer vision is to write computer programs that can interpret images (and videos)
- What are some of the challenges?
- Applications?

Optical character recognition



Long-term work on digits, AT&T labs

deskew

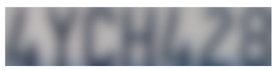
binarize

segment

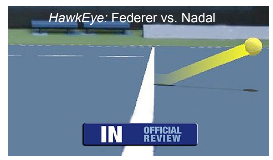
recognize

License plate readers

and ways to get around them!



Sports



[machines vs. humans]
"The balls moving so fast these days that sometimes its impossible for anyone to see, even a trained official.
- James Blake

Sportvision

What are some of the problems that these two systems need to handle?

- The system has to know the **orientation of the field with respect to the camera** so that it can paint the first-down line with the correct perspective from that camera's point of view.
- The system has to know, in that same perspective framework, exactly **where every yard line is**.
- Given that the cameraperson can move the camera, the system has to be able to **sense the camera's movement** (tilt, pan, zoom, focus) and **understand the perspective change** that results from the movement.
- Given that the camera can pan while viewing the field, the system has to be able to **recalculate the perspective** at a rate of 30 frames per second as the camera moves.
- A football field is not flat -- it crests very gently in the middle to help rainwater run off. So the line calculated by the system has to appropriately **follow the curve of the field**.
- A football game is filmed by **multiple cameras** at different places in the stadium, so the system has to do all of this work for several cameras.
- The system has to be able to **sense when players, referees or the ball cross over the first-down line** so it does not paint the line right on top of them.
- The system also has to **be aware of superimposed graphics** that the network might overlay on the scene.

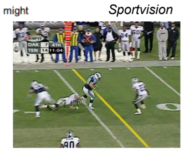
high-resolution encoders on the cameras

detailed field model ~ crest!

color palettes: ***in*** and ***out***

slight delay in the network feed

Sportvision



Challenges

- orientation of the field with respect to camera
- handle camera movement
  - recalculate perspective
- where the yard lines are
- multiple cameras
- don't paint over players refs!
- other superimposed graphics

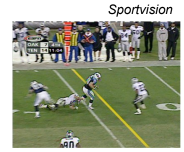
high-resolution encoders on the cameras

detailed field model

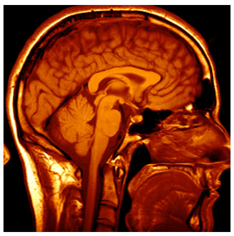
color palettes: ***in*** and ***out***

slight delay in the network feed

Sportvision



+ Medical imaging



3D imaging: MRI, CT

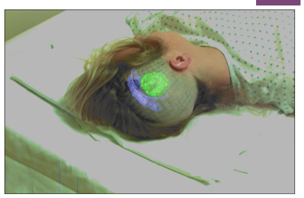


Image guided surgery: Eric Grimson @ MIT

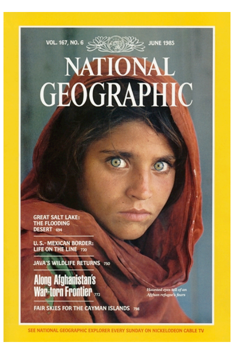
+ Face detection

on many cameras…

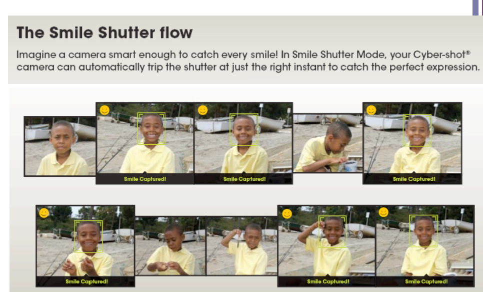
Recognition is more difficult…
but products are pushing that way!

http://www.youtube.com/watch?v=N1WC_00L0b0

+ Face Recognition

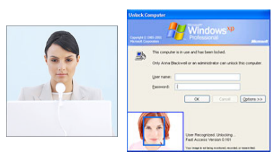


+ Smile detection?



Security

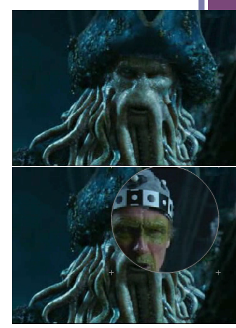
Fingerprint scanners can be vision-based devices



Face recognition systems now beginning to appear more widely
www.sensiblevision.com

key drawbacks?!

Entertainment



Shape capture

ESC Entertainment, XYZRGB, NRC

Motion capture

http://www.ilm.com/theshow/

Safety

MobilEye vision systems currently in high-end BMW, GM, Volvo model: ~70% of car manufacturers use cameras for safety

courtesy of Amnon Shashua

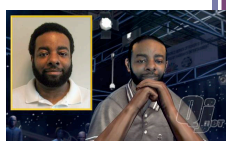
LaneHawk

simpler recognition: products passing by…

"A smart camera is flush-mounted in the checkout lane, continuously watching for items. When an item is detected and recognized, the cashier verifies the quantity of items that were found under the basket, and continues to close the transaction. The item can remain under the basket, and with LaneHawk,you are assured to get paid for it… " ~ Evolution Robotics, Pasadena.

Games and vision-based interaction

Wiimotes: infrared images



Digimask: put your face on a 3D avatar.

XBOX 360 Kinect

Camera tracking for crowd interactions…

Exploration in hostile environments (OK, robots!)

NASA's MER "Spirit" captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

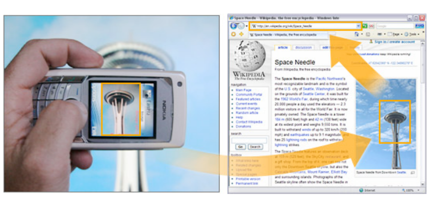
Vision systems (JPL) used for several tasks

- Panorama stitching
- 3D terrain modeling
- Obstacle detection, position tracking
- slip detection on uncertain terrain

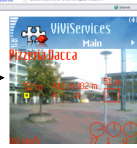
Larry Mathies, CMU

Object recognition with mobile phones

Lincoln Microsoft research



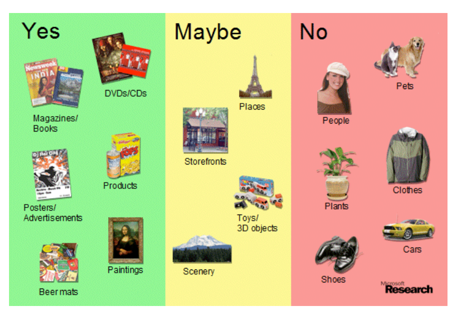
also: Point & Find, Nokia



"Hyperlinking Reality via Phones"

Object recognition with mobile phones

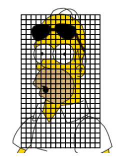
Lincoln Microsoft research



pretty much sums up the state-of-the art!

How is an image represented?

How is an image represented?

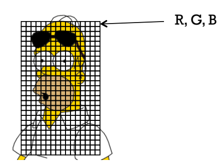


- images are made up of pixels
- for a color image, each pixel corresponds to an RGB value (i.e. three numbers)

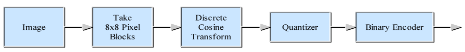
Image file formats

- BitMaP
- JPEG
- TIFF
- Gif
- Png
- …

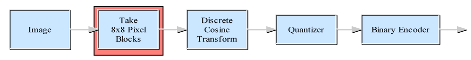
Bitmap

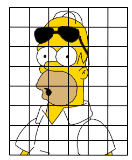


+ JPEG Compression Process

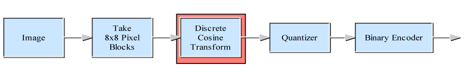


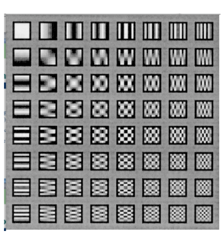
+ JPEG Compression Process



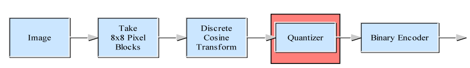


+ JPEG Compression Process



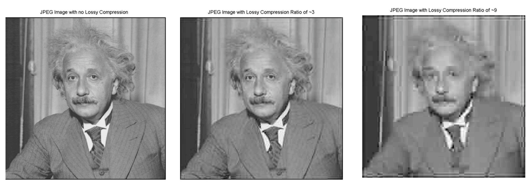


+ JPEG Compression Process



Quantizer: Weights the various spectral coefficients according to their importance, with respect to the human visual system.

+ JPEG Compression



Object Recognition

What are these?

Object Recognition

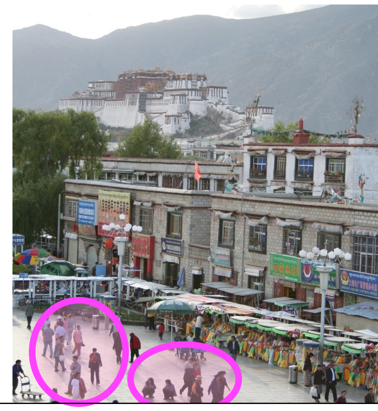
Do you recognize these people?

order are: Michael Jordan, Woody Allen, Goldie Hawn, Bill Clinton, Tom Hanks, Saddam Hussein, Elvis Presley, Jay Leno, Dustin Hoffman, Prince Charles, Cher, and Richard Nixon.

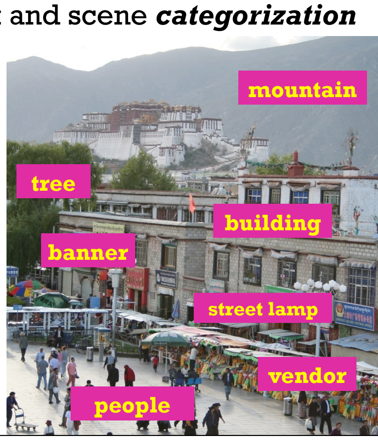
Different kinds of object recognition?

Identification: is that Potala Palace?

Detection: are there people (or faces)?



Object and scene ***categorization***



Verification: is that a lamp?

+ Recognition Question(s)

Identification: Where is *this particular* object?

Detection: Locate *all* instances of a given class

Content-based image retrieval: Find something similar

Categorization: What *kind* of object(s) is(are) present?

Verification: Is this what I think it is?

How might you arrange these, in order of difficulty?

[Csurka *et al.* 2006]:

+ Recognition Questions

More accessible

Verification: Is this what I think it is?

Identification: Where is *this particular* object?

Content-based image retrieval: Find something similar

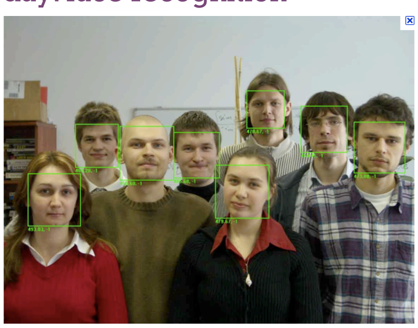
Detection: Locate *all* instances of a given class

Categorization: What *kind* of object(s) is(are) present?

More challenging

Certainly arguable !

+ Today: face recognition



+ Face recognition?

Verification: Is this what I think it is?

Identification: Where is *this particular* object?

Content-based image retrieval: Find something similar

Detection: Locate *all* instances of a given class

Categorization: What *kind* of object(s) is(are) present?

Face recognition?

Verification: Is this what I think it is?

Identification: Where is *this particular* object?

Content-based image retrieval: Find something similar

Detection: Locate *all* instances of a given class

Categorization: What *kind* of object(s) is(are) present?

Eigenfaces: how do people do it?

The "Margaret Thatcher Illusion", by Peter Thompson

Eigenfaces for recognition

Matthew Turk and Alex Pentland
J. Cognitive Neuroscience, 1991

Eigenfaces: how do people do it?

The "Margaret Thatcher Illusion", by Peter Thompson

Eigenfaces for recognition

Matthew Turk and Alex Pentland
J. Cognitive Neuroscience, 1991

Image features

- We'd like to represent an image as vector of features
  - good for machine learning techniqes
  - distance/similarity measures
  - etc.
- What are possible features?

Color

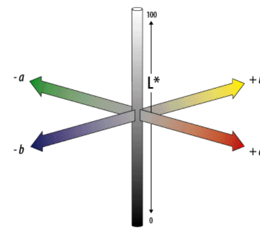
How can we represent color?

Which is more similar?

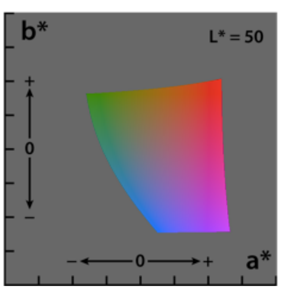
L*a*b*

L*a*b* was designed to be uniform in that perceptual "closeness" corresponds to Euclidean distance in the space.

- L – lightness (white to black)
- a – red-greeness
- b – yellowness-blueness



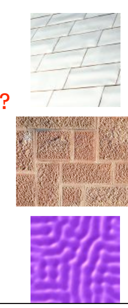
L*a*b*



Is color useful for face detection/verification?

Texture

How is texture different than color?



Texture

- Texture is not pointwise like color
- Texture involves a local neighborhood

How can we capture texture?

Local "response" to feature functions

- A "feature" is a particular low-resolution image (intensities)
- "convolution"
  - matrix dot product
  - image portions with similar intensities will have high values
- Lots of possible features!

Example: Gabor Filters

Gabor filters are Gaussians modulated by sinusoids

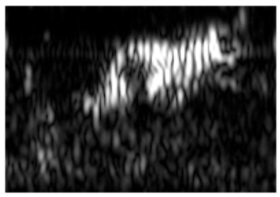
They can be tuned in both the scale (size) and the orientation

Scale: 3 at 72°   Scale: 4 at 108°   Scale: 5 at 144°

Gabor filters

What would the response look like to a vertical filter?

+ Gabor filters



Eigenfaces

Given a face, we can then calculate it's response to a number of theses filters generating a feature vector

First-thoughts for detection?

First-thoughts for identification?

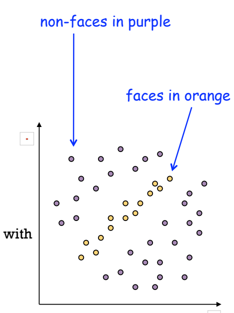
~10,000 dimensional space

Eigenfaces

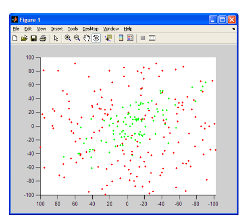
Idea: faces have distinctive appearance

There is some ***intra-class*** variation

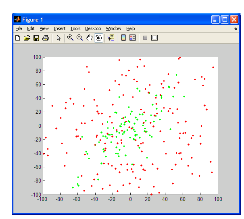
But nowhere ***near*** the ***inter-class*** variation with "everything else"



Only a few dimensions needed



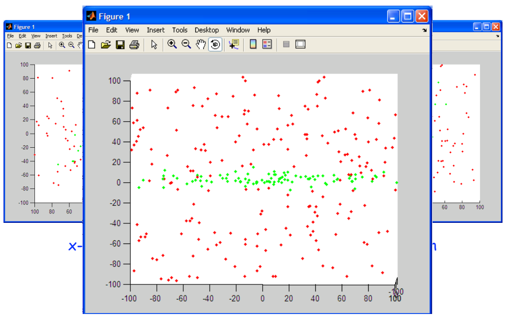
x-y projection



x-z projection

but which ones?

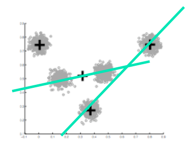
Only a few dimensions needed



this is a promising view!

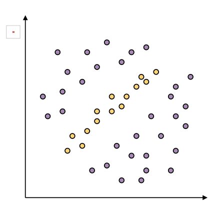
Learning a projection

- We saw data projection when we were looking at machine learning techniques… where?



- How did we figure our the projection for clustering?

Dimensionality reduction



How can we find the data's natural coordinate system?

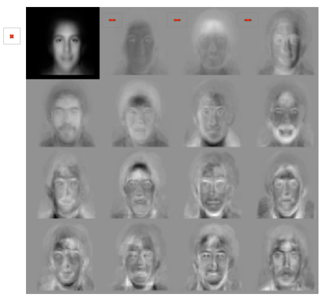
Principal component analysis

- Suppose each data point is N-dimensional
  - What directions maximize variance?

$$\begin{aligned} var(\mathbf{v}) &= \sum_{\mathbf{x}} \|(\mathbf{x}-\bar{\mathbf{x}})^{\mathbf{T}} \cdot \mathbf{v}\| \\ &= \mathbf{v}^{\mathbf{T}}\mathbf{A}\mathbf{v} \quad \text{where } \mathbf{A} = \sum_{\mathbf{x}} (\mathbf{x}-\bar{\mathbf{x}})(\mathbf{x}-\bar{\mathbf{x}})^{\mathbf{T}} \end{aligned}$$

  - Solution: the eigenvectors of the variance matrix $\mathbf{A}$
    - eigenvector with largest eigenvalue captures the most variation among training vectors $\mathbf{x}$
    - eigenvector with smallest eigenvalue has least variation
  - We can use only the top few eigenvectors
    - corresponds to choosing a "linear subspace"
      - represent points on a line, plane, or "hyper-plane"
    - these eigenvectors are known as the ***principal components***

Eigenfaces: pictures!



What do each of these mean?

Eigenfaces (plus the average face)

Projecting onto low-d eigenspace

- The eigenfaces $\mathbf{v}_1, \ldots, \mathbf{v}_K$ span the space of faces
  - A face is converted to eigenface coordinates by

$$\mathbf{x} \rightarrow (\underbrace{(\mathbf{x}-\overline{\mathbf{x}}) \cdot \mathbf{v}_1}_{a_1}, \underbrace{(\mathbf{x}-\overline{\mathbf{x}}) \cdot \mathbf{v}_2}_{a_2}, \ldots, \underbrace{(\mathbf{x}-\overline{\mathbf{x}}) \cdot \mathbf{v}_K}_{a_K})$$

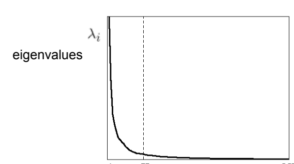
$$\mathbf{x} \approx \overline{\mathbf{x}} + a_1\mathbf{v}_1 + a_2\mathbf{v}_2 + \ldots + a_K\mathbf{v}_K$$

Eigenfaces: pictures!

Eigenfaces (without the average face)

Progressive reconstructions…

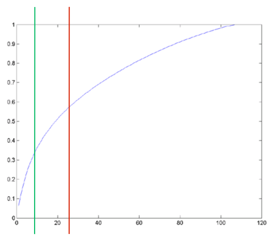
How many dimensions?



The hope…

- How many eigenfaces to use?
- Look at the decay of the eigenvalues
  - the eigenvalue tells you the amount of variance "in the direction" of that eigenface
  - ignore eigenfaces with low variance

How many dimensions?



In practice

- Total variance captured vs. number of eigenfaces used
  - K = 10 captures about 36% of the variance
  - K = 25 captures about 56%

Eigenfaces: recognition (id)

32 test cases
Novel image on left; best-matching image on right

Eigenfaces: recognition (id)

Different lighting conditions

Different facial expressions

On which set do you think eigenfaces will perform better?

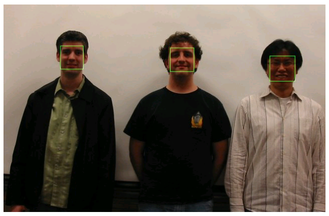
Eigenfaces: recognition (id)

Different lighting conditions

Different facial expressions

9/16 for lighting changes … 23/26 for expression changes

Eigenfaces: detection

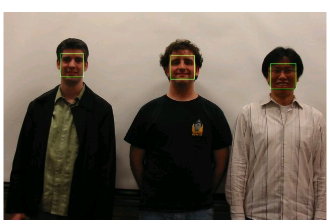
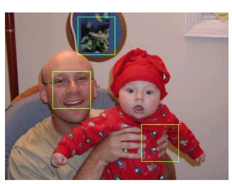


How can we do this using eigenfaces?

Eigenfaces: detection

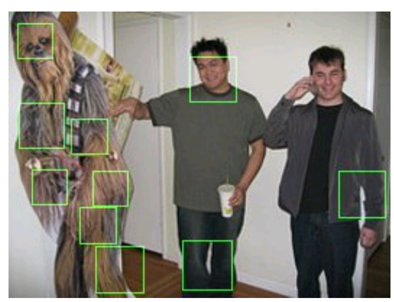
Difficult to avoid false positives…
Top 4

Eigenfaces: detection

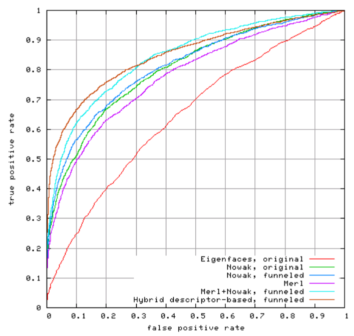
Difficult to avoid false positives…
Top 3

Eigenfaces: detection



Top few

Receiver-operating curve



shows true positive vs. false positive rate

What's wrong with detection?

each top image, projected onto eigenspace

How do we improve this?

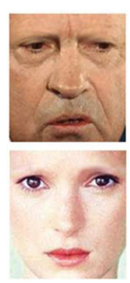
What's wrong with detection?

each top image, projected onto eigenspace

Reasonable once we have an image face (recognition)

Not so good at finding faces (detection)

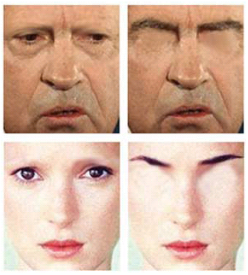
+ ***What** parts are important?*



what's missing?

who are these two people?

+ ***What*** *parts are important?*



eyes vs. eyebrows

who are these two people?

+ ***What*** *parts parts are important?*

Nixon

Winona Ryder

who are these two people?

+ ***Robust*** real-time face detection

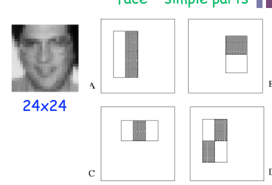
- Paul A. Viola and Michael J. Jones
- *Intl. J. Computer Vision*
- 57(2), 137–154, 2004

Learn which "parts" are most important…

+ Image features

- "Rectangle/box filters"
  - Similar to Haar wavelets
- ***Differences*** between sums of pixels in adjacent rectangles
- Simple thresholding

face ~ simple parts

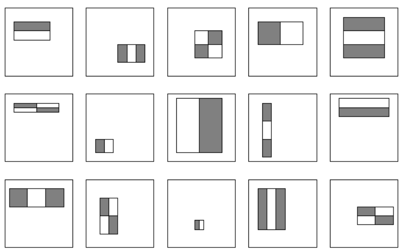


$$h_t(x) = \begin{cases} +1 & \text{if } f_t(x) > \theta_t \\ -1 & \text{otherwise} \end{cases}$$

each box filter is present or absent

gray regions are subtracted (after summing)
white regions are added (after summing)

+ Huge library of filters



+ Constructing the classifier

- ***For each round of boosting: (AdaBoost)***
- Evaluate each rectangle filter on each example
- Sort examples by filter values
- Select best threshold for each filter (min error)
  - Use sorting to quickly scan for optimal threshold
- Select best filter/threshold combination
- Reweight examples
  - (There are many tricks to make this more efficient.)

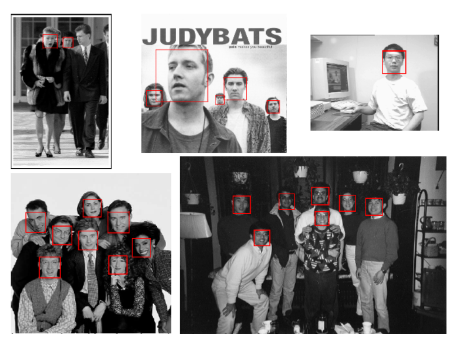
+ Characteristics of algorithm

- Feature set (…is huge about 16M features)
- Efficient feature selection using AdaBoost

- New image representation
- Cascaded Classifier combining simple weak classifiers for rapid detection

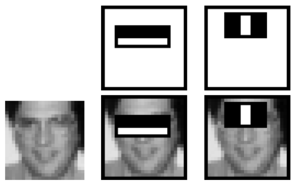
➢ Fastest known face detector for gray scale images

Viola and Jones: Results



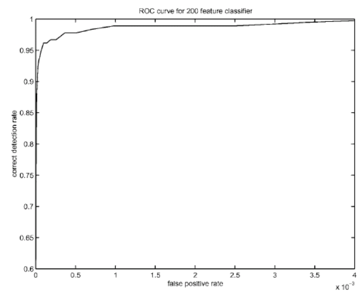
+ First two filters

- First classifier:
  - 2 features
  - 100% detection
  - 40% false detection



- The whole cascade:
  - 38 stages
  - 6000 features in total
  - On dataset with 507 faces and 75 millions sub-windows, faces are detected using 10 feature evaluations on average.
  - On average, 10 feature evals/sub-window

Robustness…



Receiver – operating curve for best 200 features

shows true positive vs. false positive rate

+ Summary (Viola-Jones)

- Fastest known face detector for gray images
- Three contributions with broad applicability:
  - Cascaded classifier yields rapid classification
  - AdaBoost as an extremely efficient feature selector
  - Rectangle Features + Integral Image can be used for rapid image analysis

But, there are better ones out there…

+ *Other algorithms are available…*

+ Happy face!