CS 528: Mobile and Ubiquitous Computing

Lecture 5a: Facial Analysis: How it works

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Final Project: 1 Slide

Reminder: Final Project

- 1-slide from group in 2 weeks Wednesday October 14:
  - 2/30 of final project grade
- Slide should cover 3 aspects
  1. **Problem you intend to work on either:**
     - App that helps WPI students cope with COVID
     - Points awarded for difficulty, components used (location, sensor, camera, ML)
     - If games, must gamify solution to real world problem
  2. **Why this problem is important**
     - E.g. WPI students can't find places to study during COVID
  3. **Summary of envisioned mobile app (?) solution**
     1. E.g. Mobile app tracks availability of study spaces. WPI students can check using app
- You can:
  - Bounce ideas of me (email, or in person)
  - Change idea any time

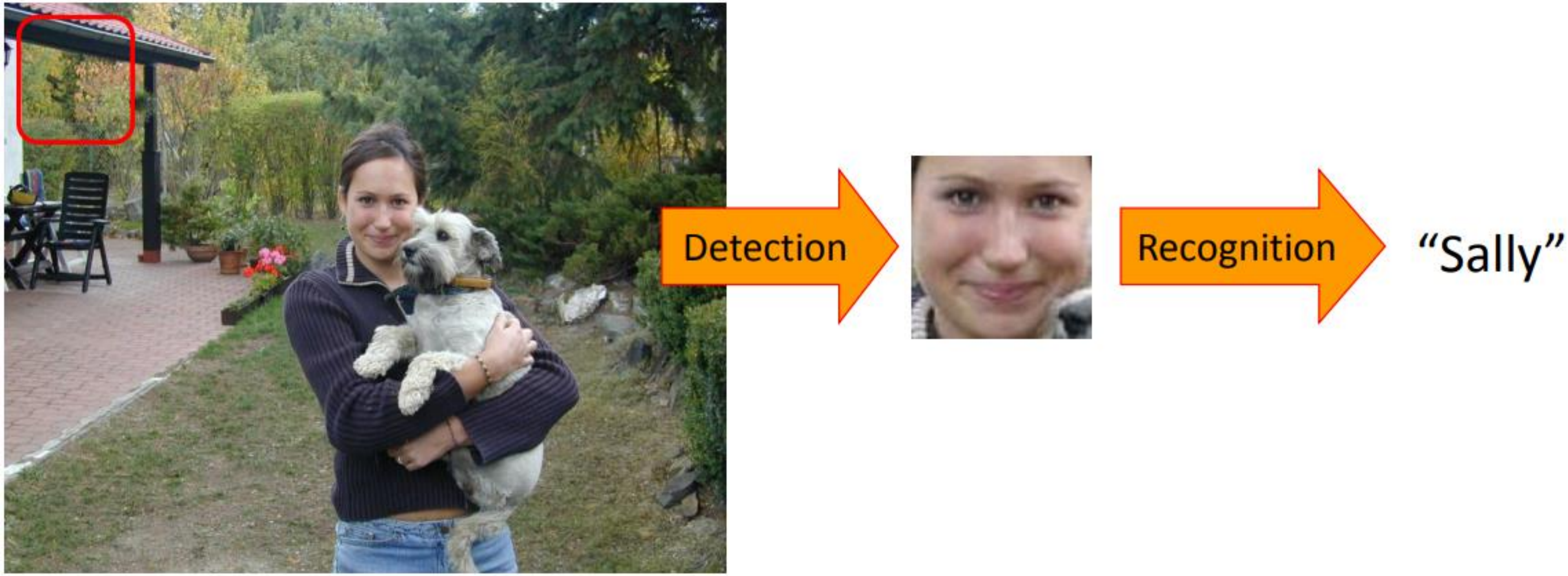
Final Project: Difficulty Score

- **Project execution, presentation, paper:** 80%
- **Project difficulty score:** 20%
- **Mobile Components and Android UI (4 points each)**
  - Every 5 Android screens (A maximum of 8 points can be earned for the UI)
  - Playback audio/video
  - Maps, location sensing
  - Camera: simply taking pictures
- **Ubiquitous Computing Components & Android UI (6 points each)**
  - Activity Recognition, sensor programming, step counting
  - GeoFencing, Mobile Vision API: e.g. Face/barcode detection/tracking
- **Machine/Deep Learning (10 points each)**
  - Machine/deep learning (i.e. run study, gather data or use existing dataset to classify/detect something)
  - Program Android, machine learning/deep learning components

Reminder: Detection vs Recognition

Ref: Adriana Kovashka, Introduction to Vision (CS 1674), U. of Pittsburgh, fall 2016

- Detection: Find (draw squares around) all faces in image
- Recognition: Whose face is in the image



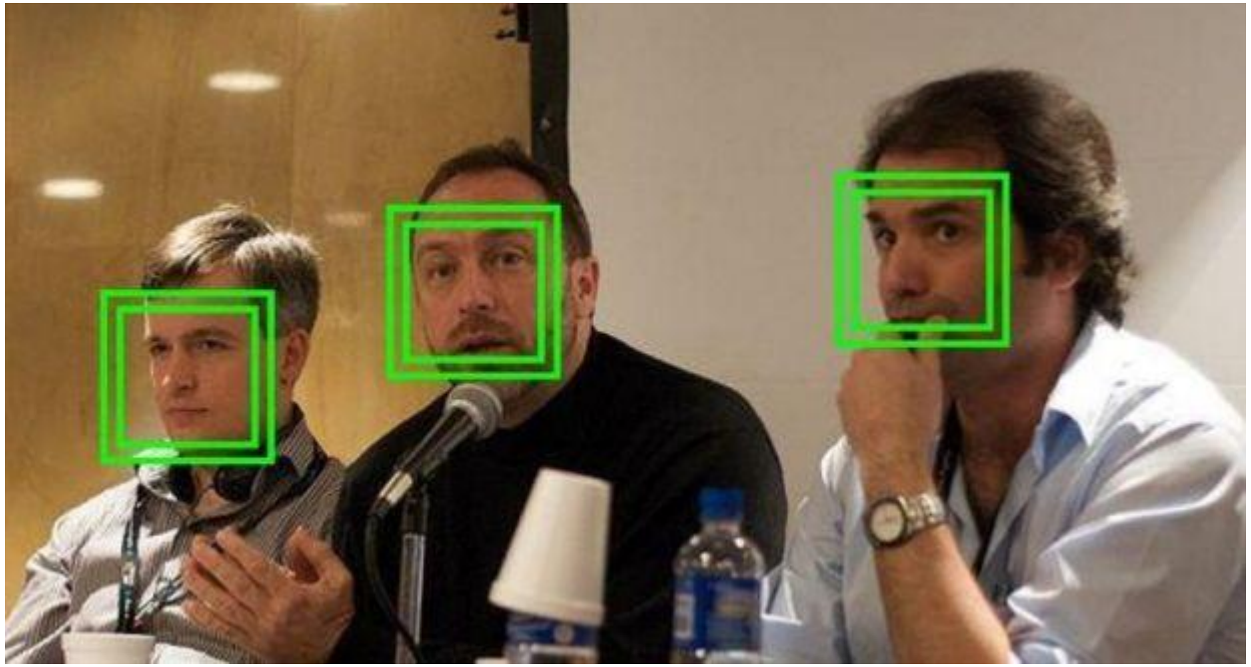
Detection

Recognition

“Sally”

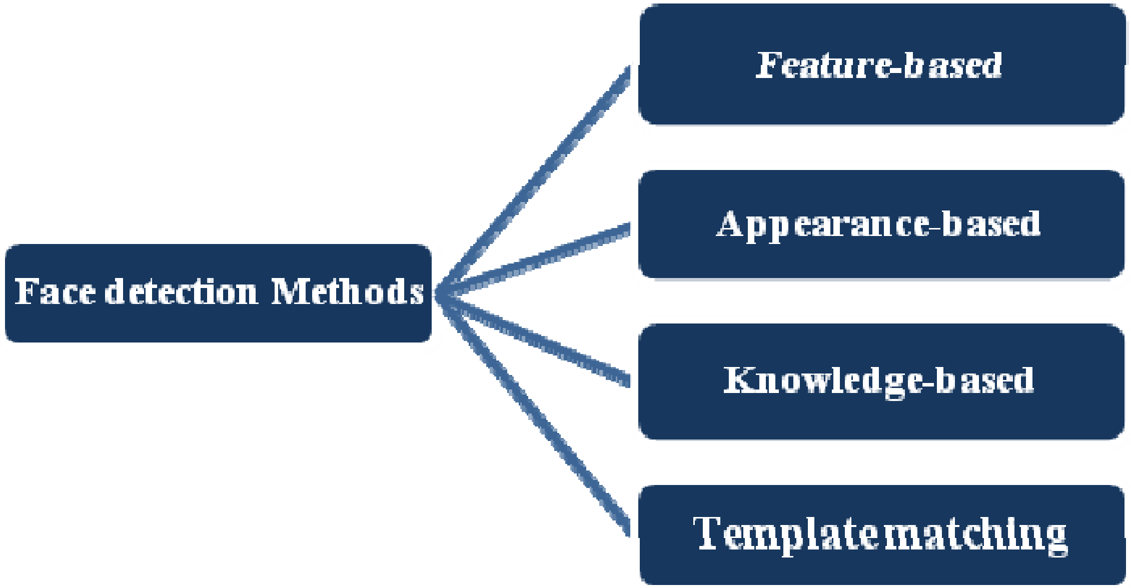
Uses of Face Detection

- Detect Faces in surveillance images
- Cameras use it to detect faces in a picture
- Facbook: detect faces in an image, recognize them



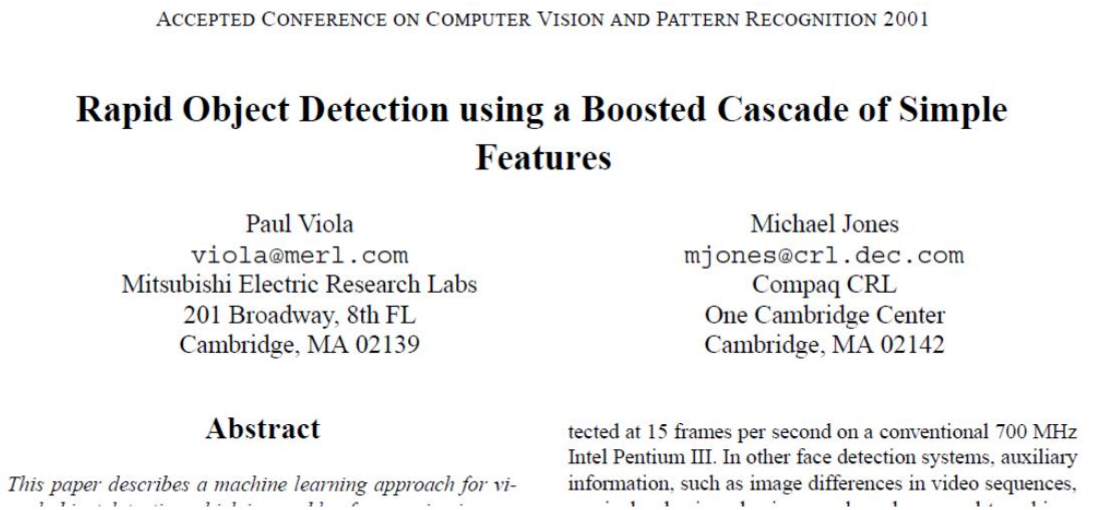
Types of Face Detection Algorithms

- Categorization by Yang, M.H., Kriegman, D.J. and Ahuja, N., 2002. Detecting faces in images: A survey. *IEEE Transactions on pattern analysis and machine intelligence*, *24*(1), pp.34-58.
- **Knowledge-based:** Rules based on human knowledge. E.g. relative positions and distances of parts (nose, eyes, mouth, etc)
- **Feature-based:** Extract visual attributes (color, texture, shape), train machine learning classifier to distinguish facial vs. non-facial regions
- **Template:** Divide face into parts (e.g. mouth, eyes), compare/match parts to templates (or standard face patterns)
- **Appearance-based:** Generates templates from representative set of faces



Face Detection: Voila Jones Algorithm

- Most popular method, published in CVPR 2001 (top computer vision conference)
- Windows based: Draw candidate windows, decides if it contains face or not
- First fast, real time, still used today
- Challenge?
  - Lots of pixels in image (millions)
  - But faces are rare (0 – 10 per image)
  - Window evaluation must be computationally efficient, fast
  - But also low false positive rate (< 1 in 1 million)
  - False Positive: Say it's a face but it's not



ACCEPTED CONFERENCE ON COMPUTER VISION AND PATTERN RECOGNITION 2001

Rapid Object Detection using a Boosted Cascade of Simple Features

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Abstract

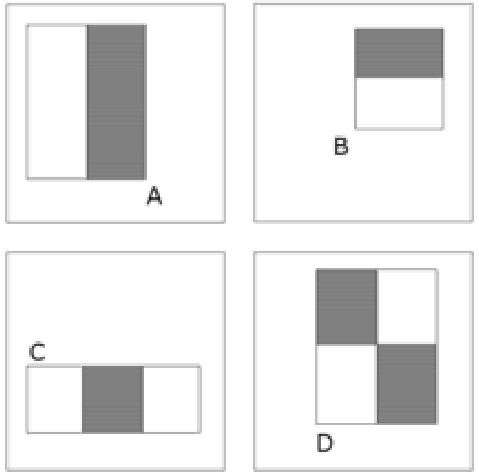
This paper describes a machine learning approach for vi-

tected at 15 frames per second on a conventional 700 MHz Intel Pentium III. In other face detection systems, auxiliary information, such as image differences in video sequences,

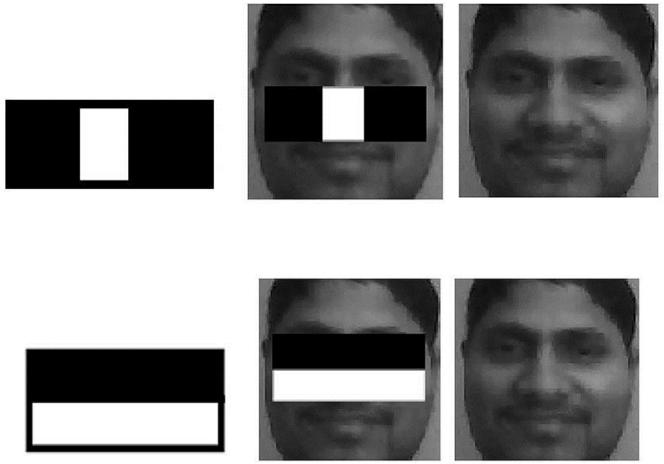
Voila Jones: 4 Stages

1. Haar Feature Selection
2. Creating an Integral Image
3. Adaboost Training
4. Cascading Classifiers

Step 1: Haar Feature Selection



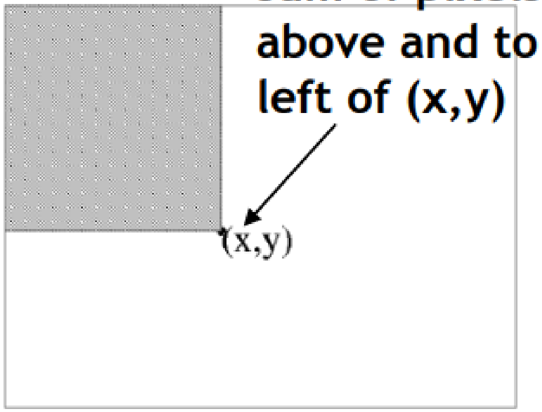
- Features: rectangular patterns
- Calculate sums of pixel values within rectangles
- Example:
  - Overlay feature A over image
  - Calculate (sum of pixels in white rectangle) – (sum of pixels in gray rectangle)
- So what?
  - All faces have common properties
  - E.g.
    - Eye region is darker than upper cheeks
    - Bridge of nose is brighter than eyes



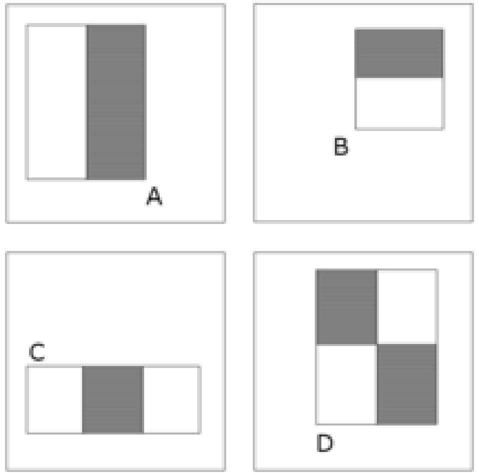
Step 2: Integral Image

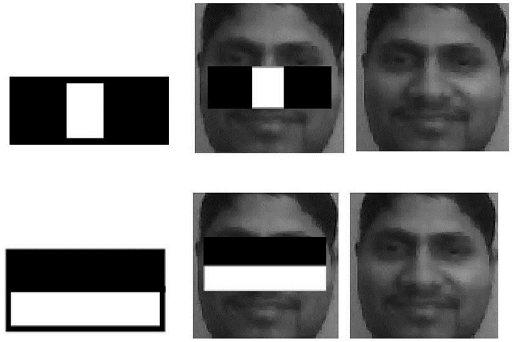
- Efficient way to calculate sum of pixel values within rectangles
  - Calculate (sum of pixels in white rectangle) – (sum of pixels in gray rectangle)

Value at (x,y) is sum of pixels above and to the left of (x,y)



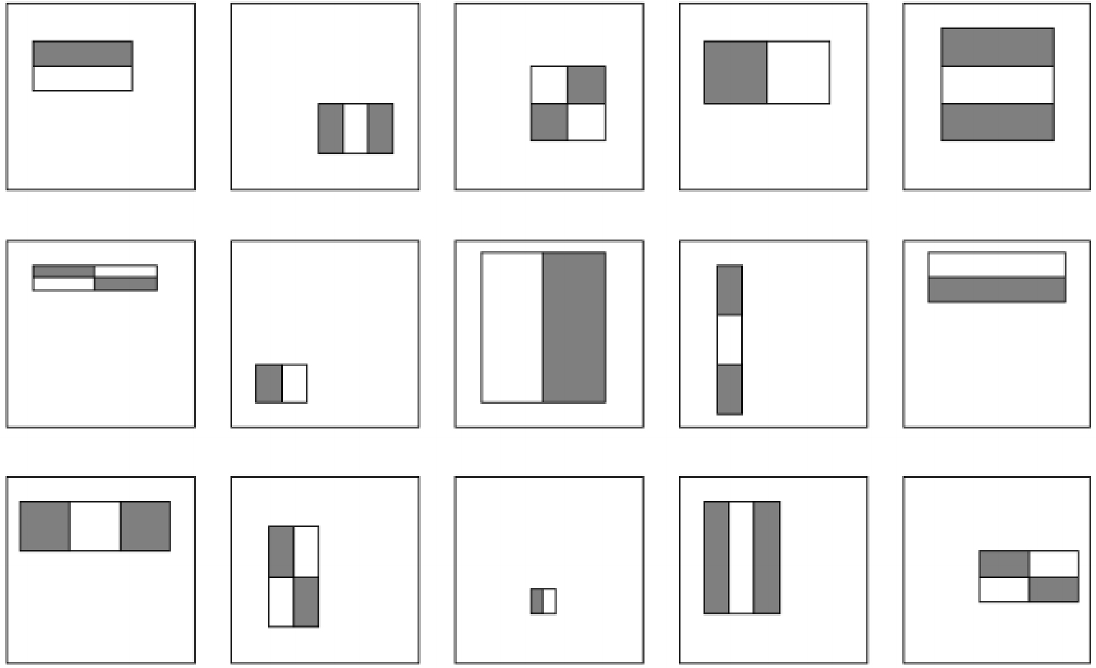
Integral image





Step 3: AdaBoost Classifier

- Want to overlay various scales, and positions of the 4 feature types over the face
  - Determine which specific shapes, positions, scales are discriminative
- Lots of permutations and combinations: E.g. 180,000 features per 24 x 24 pixel window
- Use an AdaBoost classifier (Machine Learning)

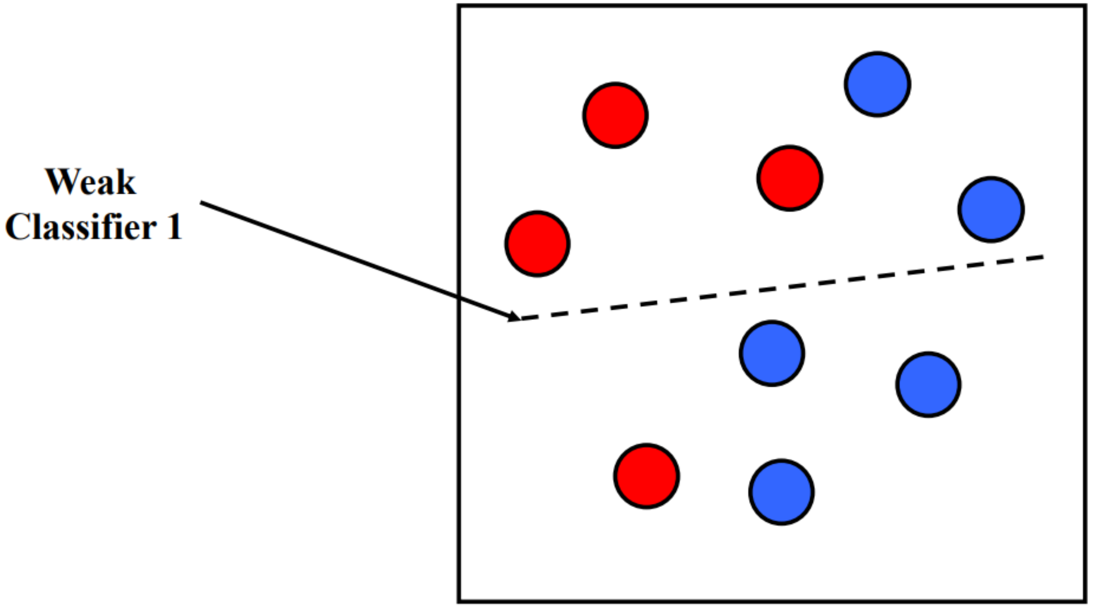


Boosting: Training

Ref: Adriana Kovashka, Introduction to Vision (CS 1674), U. of Pittsburgh, fall 2016

- Initially, weight each training example equally
- In each boosting round:
  a) Find the weak learner that achieves the lowest weighted training error

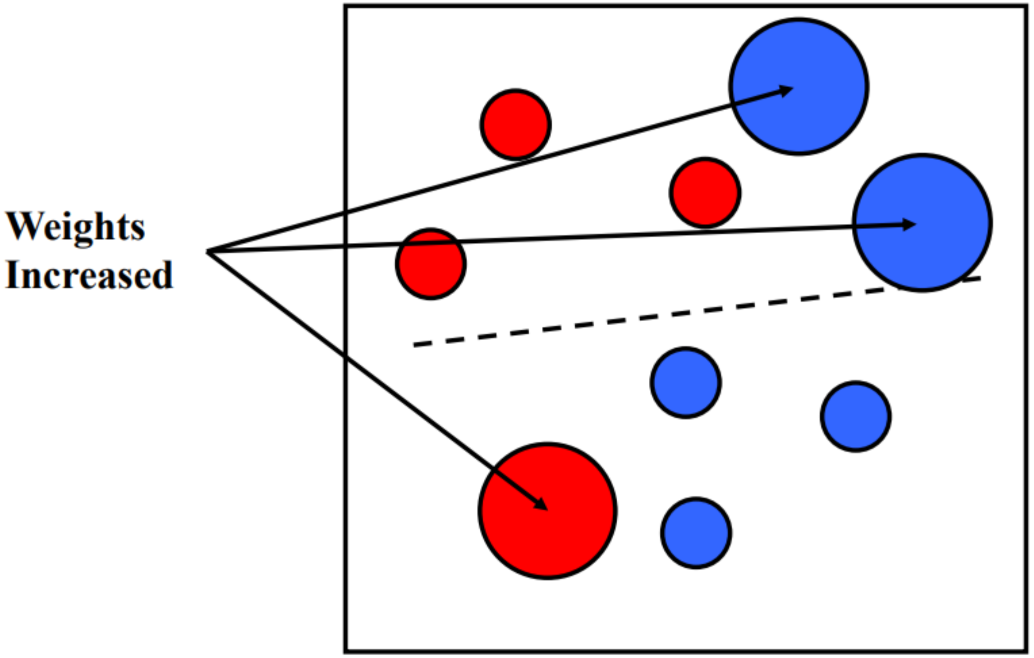
  (Find dividing line that has lowest total distance from all the points in the training set)



Boosting: Training

Ref: Adriana Kovashka, Introduction to Vision (CS 1674), U. of Pittsburgh, fall 2016

- In each boosting round:
  a) Find the weak learner that achieves the lowest weighted training error
  b) **Increase weights of training examples misclassified by current weak learner (Increase weights of examples on wrong side of dividing line)**



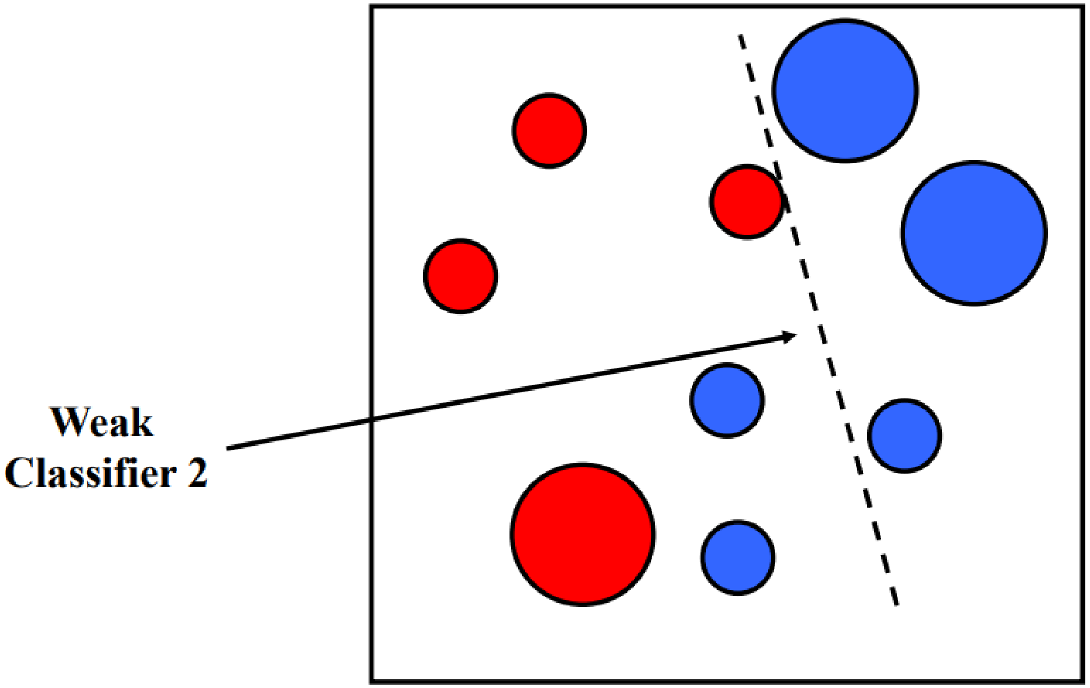
Boosting: Training

Ref: Adriana Kovashka, Introduction to Vision (CS 1674), U. of Pittsburgh, fall 2016

- Round 2: Repeat a) and b) again to find weak classifier 2

  a) **Find the weak learner that achieves the lowest weighted training error**

  (Note: weighted examples results in different dividing line)



Boosting: Training

Ref: Adriana Kovashka, Introduction to Vision (CS 1674), U. of Pittsburgh, fall 2016

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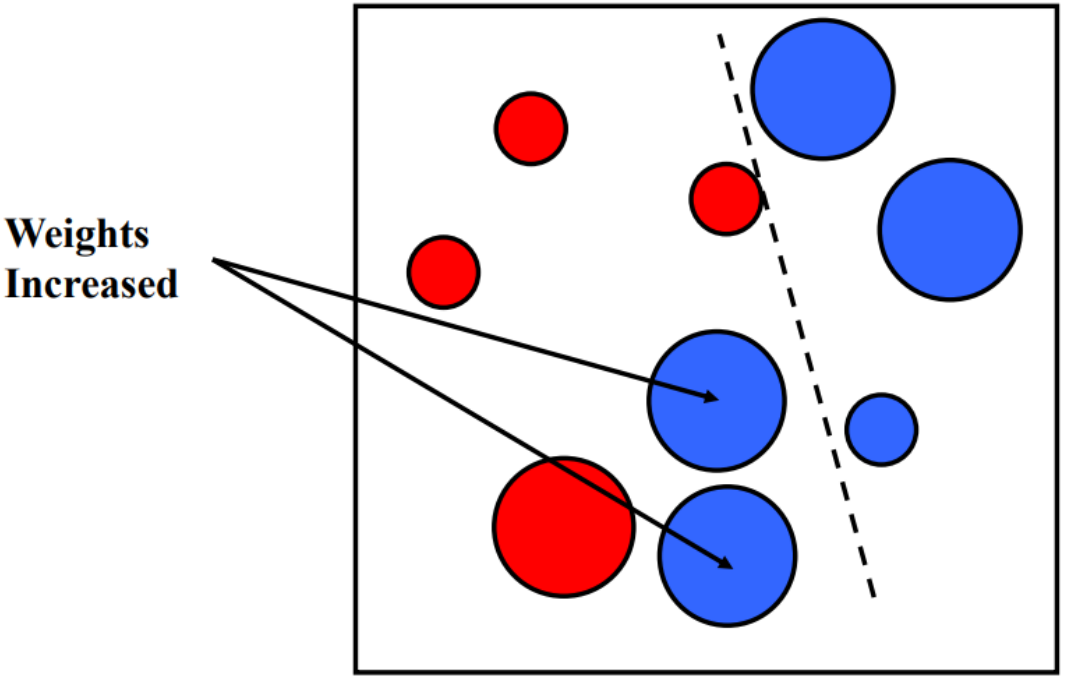
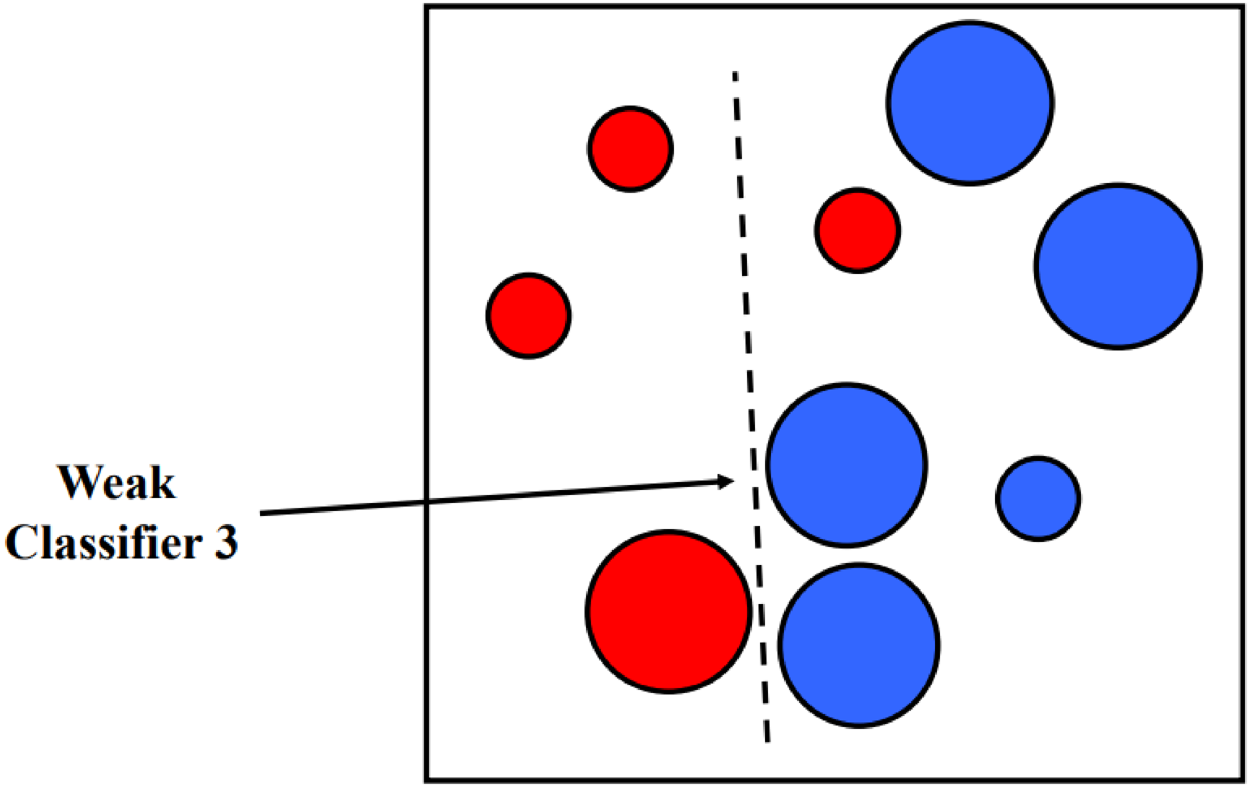


Boosting: Training

Ref: Adriana Kovashka, Introduction to Vision (CS 1674), U. of Pittsburgh, fall 2016

- Round 3: Repeat a) and b) again to find weak classifier 3

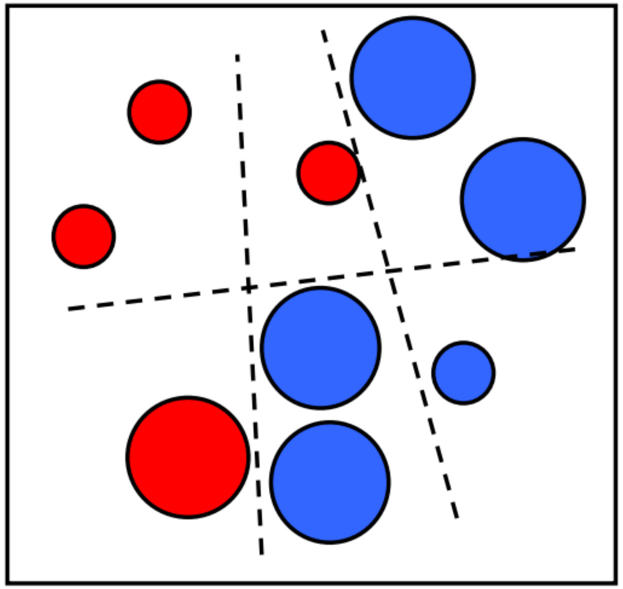


Boosting: Training

Ref: Adriana Kovashka, Introduction to Vision (CS 1674), U. of Pittsburgh, fall 2016

- Final classifier is combination of weak classifiers.
- i.e. for each point to be classified, test against:
  - Classifier 1
  - Classifier 2
  - Classifier 3… etc

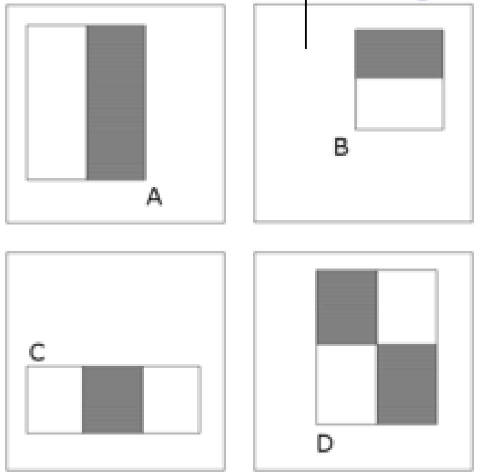
Final classifier is
a combination of weak
classifiers

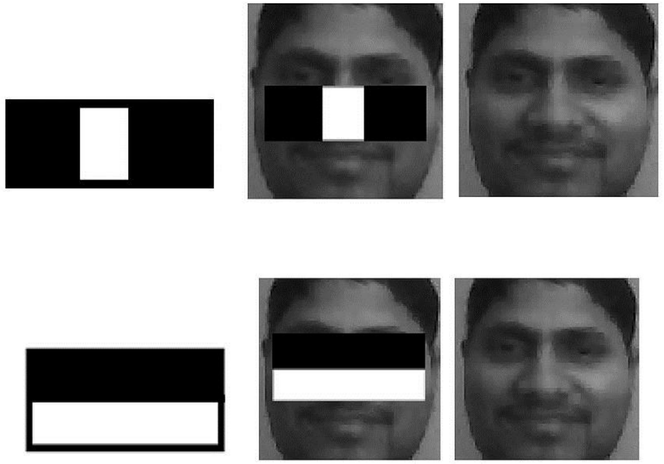


- Different algorithms, formulas for re-weighting and combining weak learners
  - E.g. AdaBoost

Step 3: AdaBoost Classifier

- Examine windows within an image
- What to determine if there’s a face in that window
- Overlay 4 feature patterns over various parts of the window
- Find which of 4 feature patterns + locations that indicate that window contains face
  - Patterns + position + scale that discriminate face vs. non-face used as weak classifiers
  - Use Boosted combination of multiple weak classifiers as final classifier
  - Form cascade of weak classifiers, reject negatives quickly

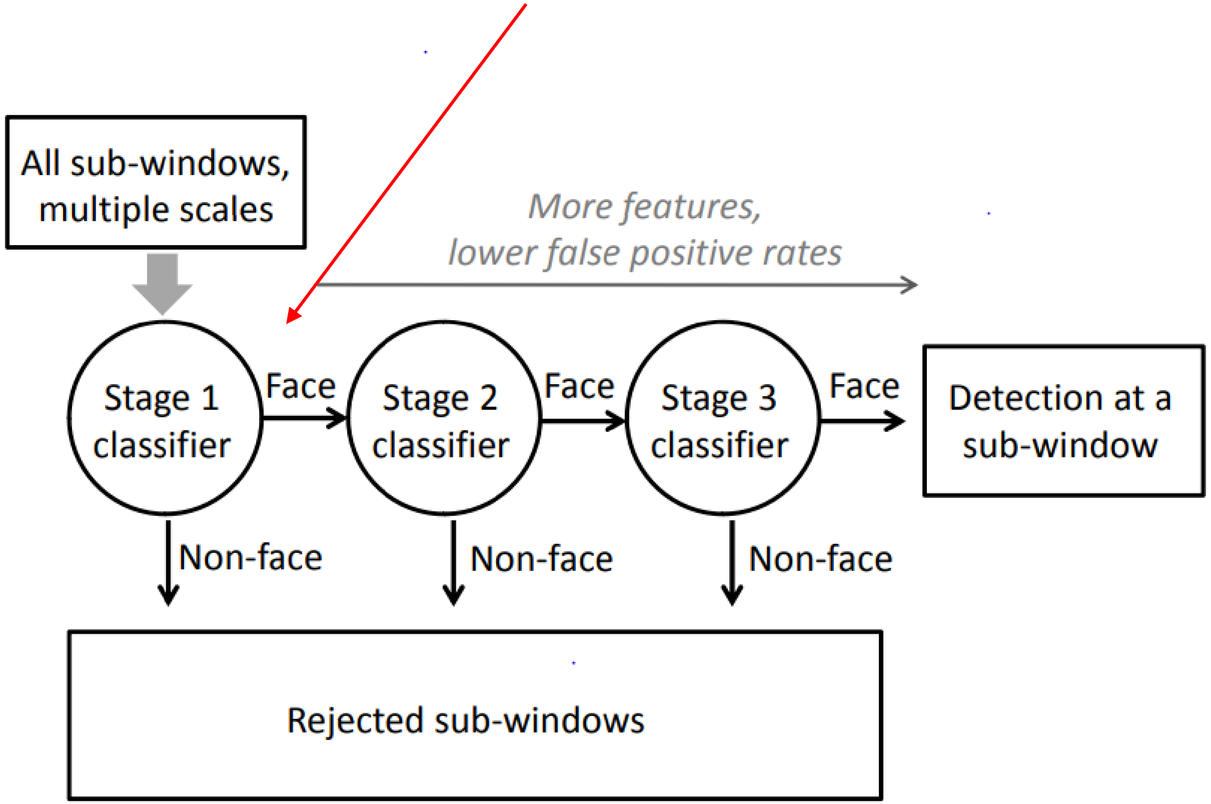




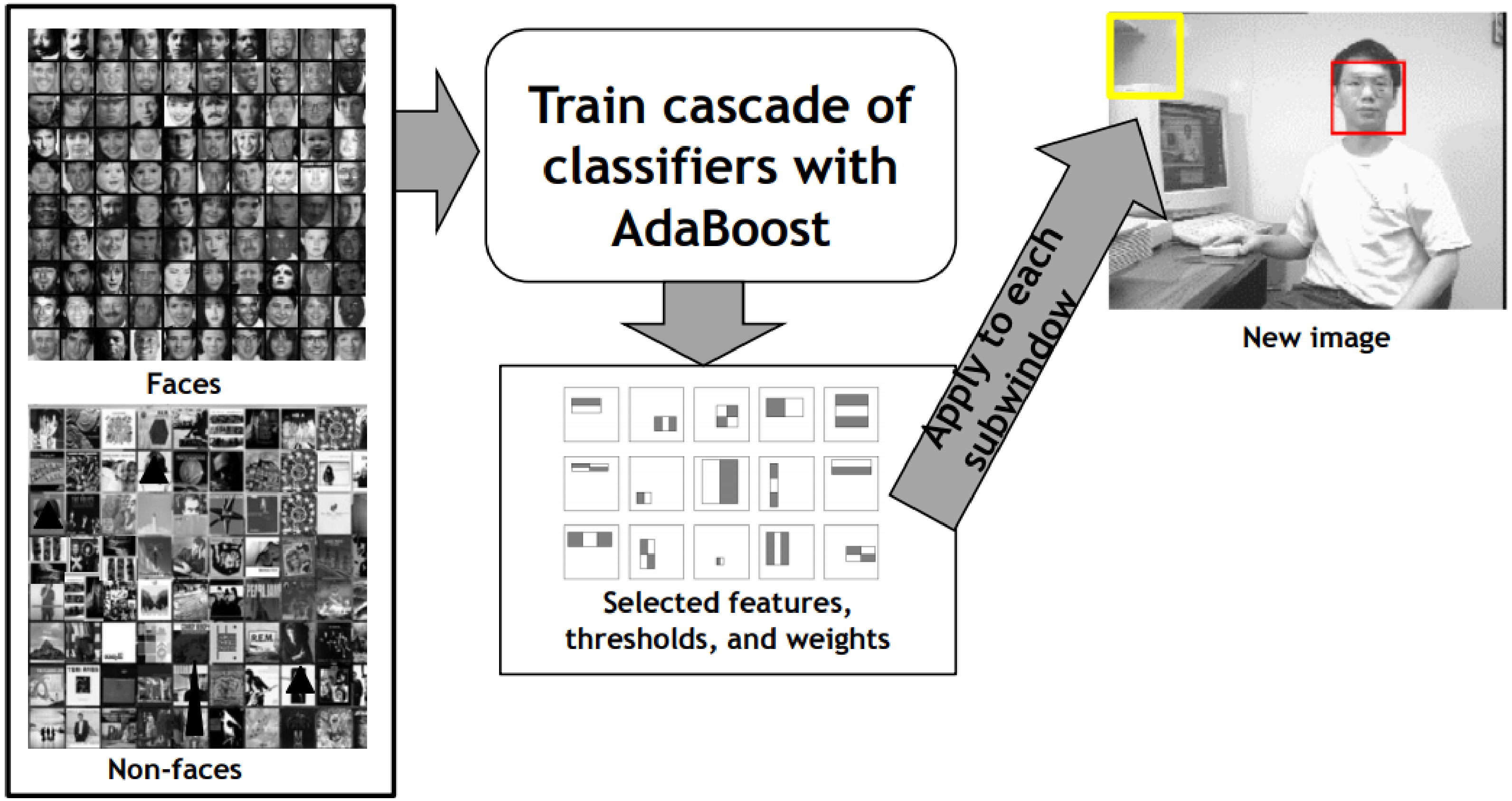
Step 4: Cascade of Classifiers

Ref: Grauman, K. and Leibe, B., 2011. Visual object recognition. *Synthesis lectures on artificial intelligence and machine learning*, 5(2), pp.1-181.

- Form cascade: Use weak classifiers one after the other
- Reject non-faces quickly by placing features with low false negative rates early on



Voila Jones Algorithm: Summary



Faces

Non-faces

Train cascade of classifiers with AdaBoost

Selected features, thresholds, and weights

Apply to each subwindow

New image

Train with 5K positives, 350M negatives

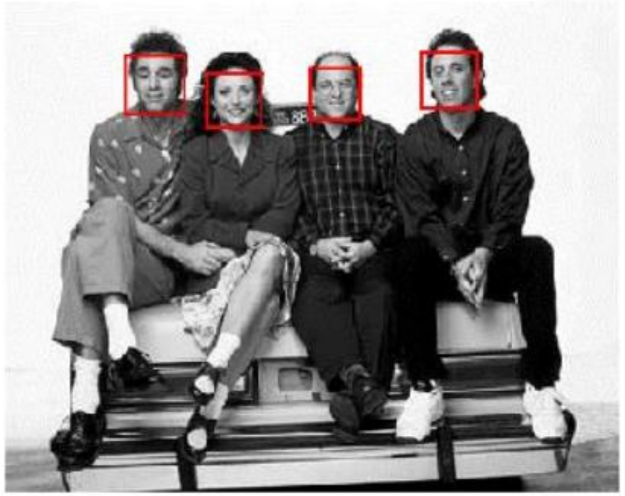
Real-time detector using 38 layer cascade (0.067s)

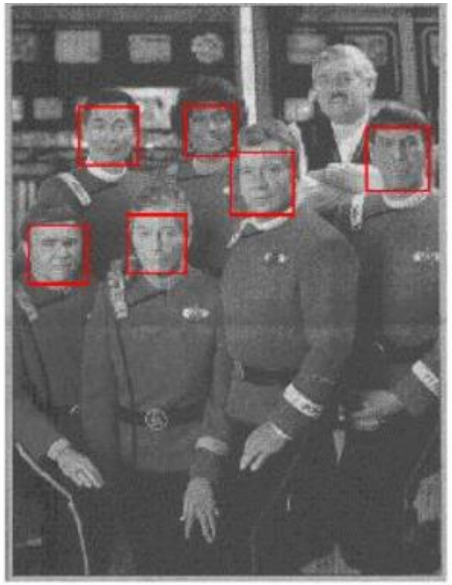
Training: slow

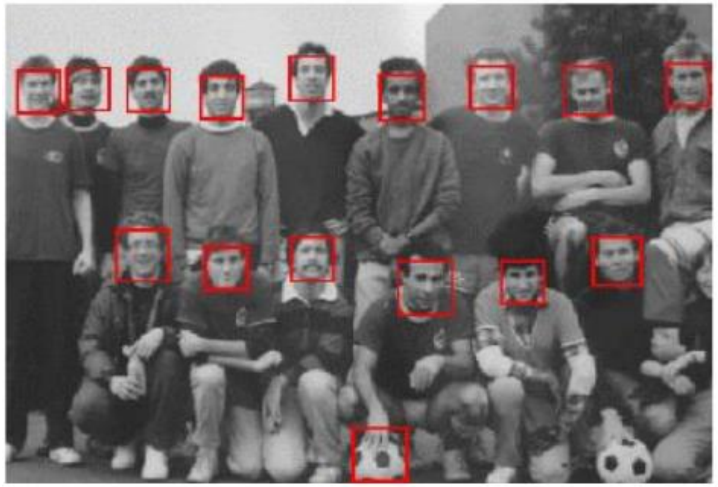
Test: fast

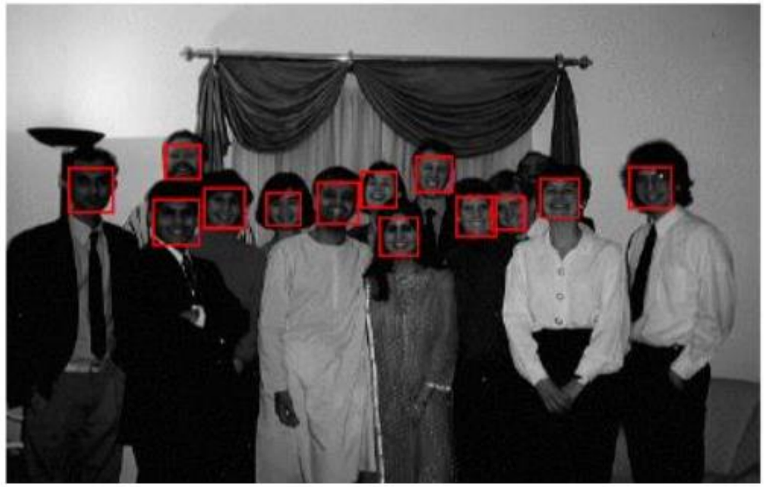
- Integral image
- Cascade of classifiers

Voila Jones: Results



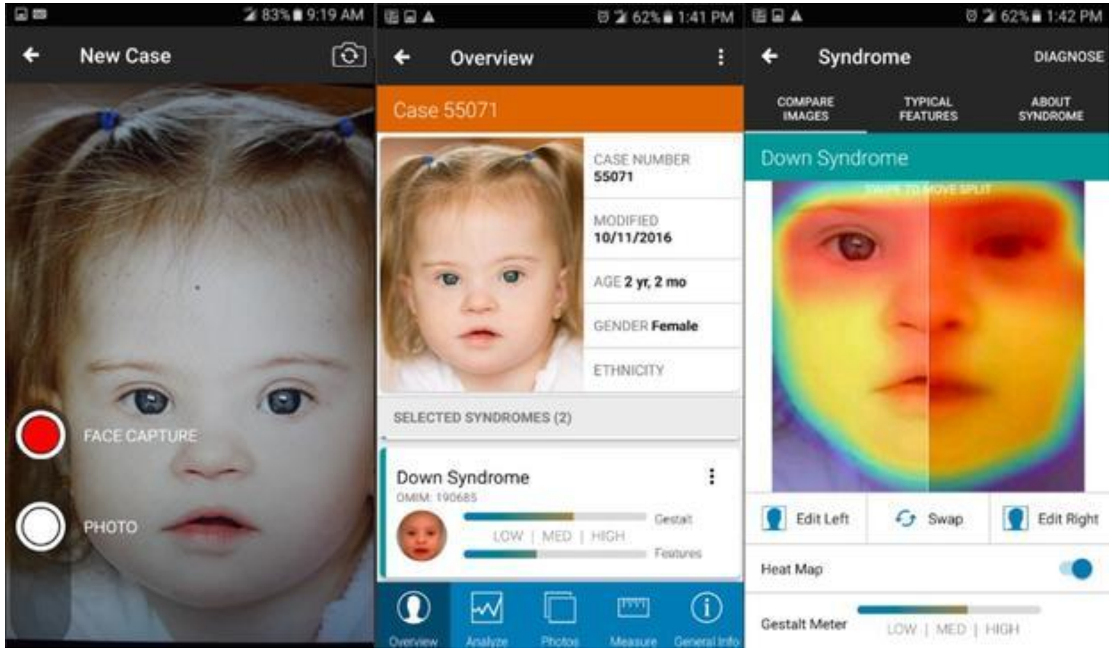






Face Recognition: Uses

- Device security:
  - Recognize owner’s face, use as their device password
- Identify genetic disorders:
  - Analyze, compare faces to databases of people with various disorders
  - E.g. Face2gene app, DeepGestalt software
- Prevent shoplifting
  - Recognize past shoplifters, notify owner if they visit
- Check underage alcohol/tobacco buyers
  - Automatically assess buyers age from their face
- Security in schools
  - Recognize criminals, sex offenders
- Airline ticketing:
  - Use your face as your ticket



Case 55071

CASE NUMBER 55071

MODIFIED 10/11/2016

AGE 2 yr, 2 mo

GENDER Female

ETHNICITY

SELECTED SYNDROMES (2)

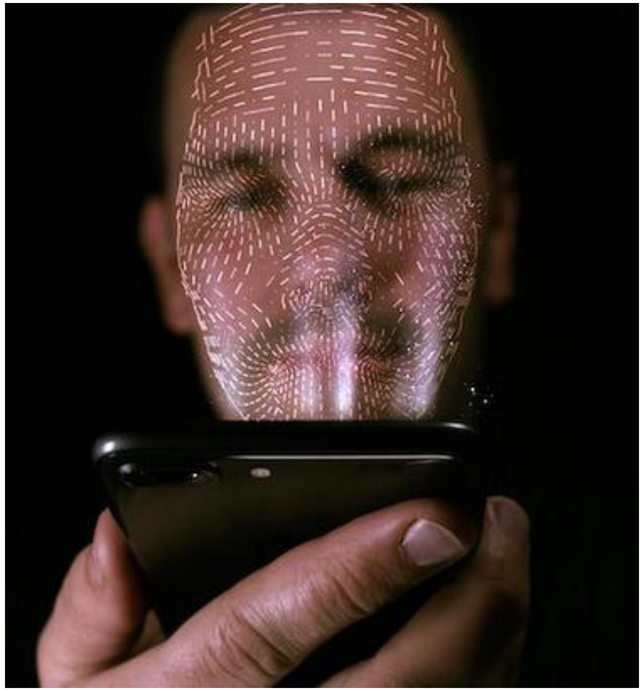
Down Syndrome

OMIM: 190685

Heat Map

Android Face Recognition/Face Unlocking

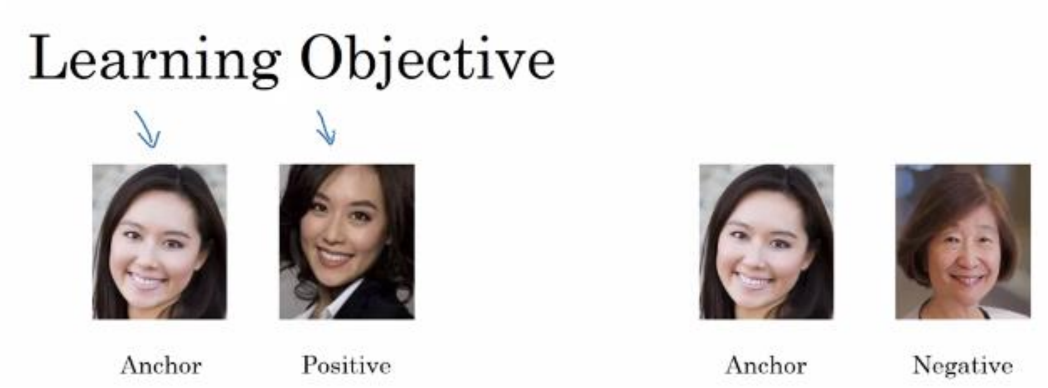
- Mostly used for security, recognize owners face in place of password
  - Not definitely more secure but faster, more convenient (no forgotten passwords)
- Basic version compares stored picture with picture captured by front-facing camera
- Thief can fool system by presenting a picture of owner
- Available on Pixel 4, well executed
  - Cannot be fooled by similar people, photos



Face Recognition: Triplet Loss

- Uses neural networks a lot these days
  - Ref: Schroff *et al*, 2015, FaceNet: A Unified embedding for face recognition and clustering
- Given:
  - Anchor: reference image
  - Postive: Positive example
  - Negative: Negative example

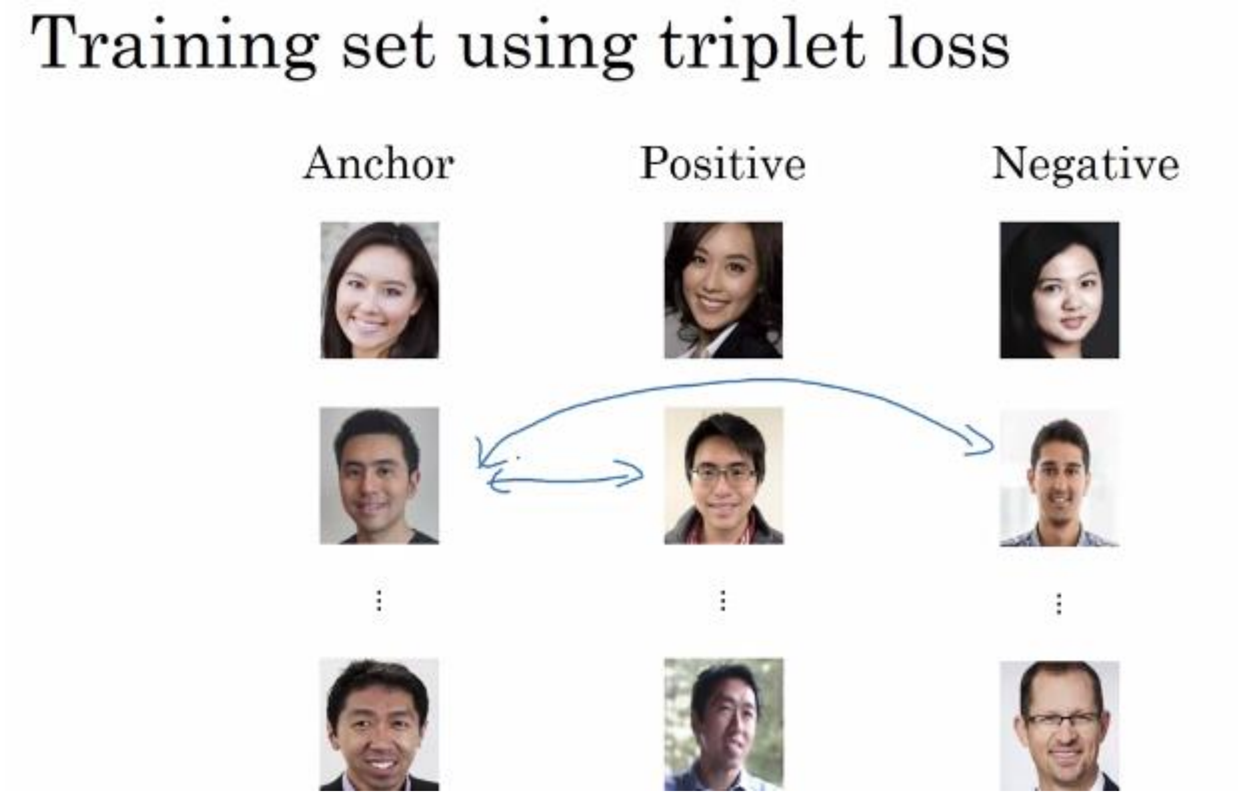
Triplet Loss



- Defines loss (objective function) that learns encoding (0101000…) such that:
  - Anchor and positive close together
  - Anchor and negative far apart

Triplet Loss: Training Set

- Millions of sets of 3 (Anchor, Positive, Negative)
- Neural network learns encoding and to distinguish faces



Training set using triplet loss

Anchor

Positive

Negative

Android Networking

Android Networking Alternatives

- Android provides various alternative methods of network connection
  - Sockets: low level, multi-purpose
  - URLConnection: Higher level, over the web
  - HttpURLConnection: Web, uses the HTTP protocol

References

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- Convolutional Neural Networks Course, Deeplearning.ai, Coursera