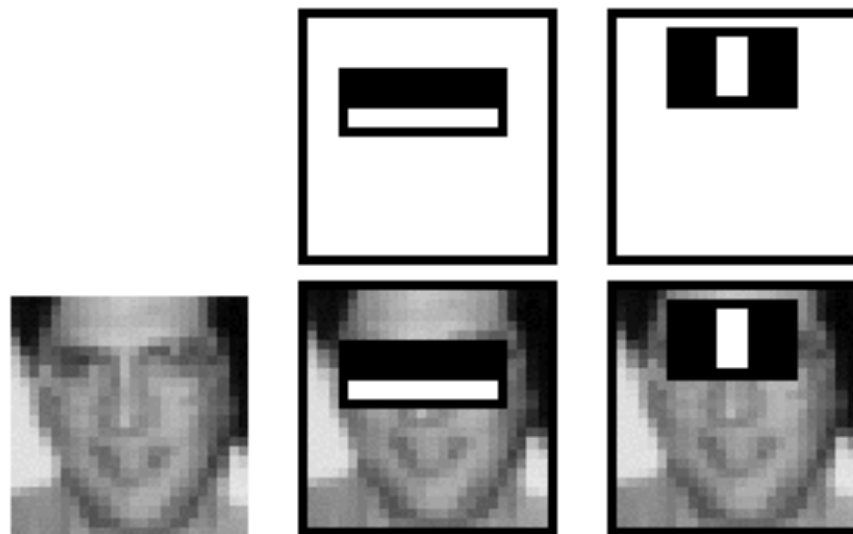# Boosting and Viola Jones

Application: Face Detection (Viola-Jones'00)

Given a rectangular window of pixels, is there a face in it?

Properties:
* Easy to come up with simple rules-of-thumb classifiers,
* Hard to come up with a single high accuracy rule

Viola-Jones Weak Learners

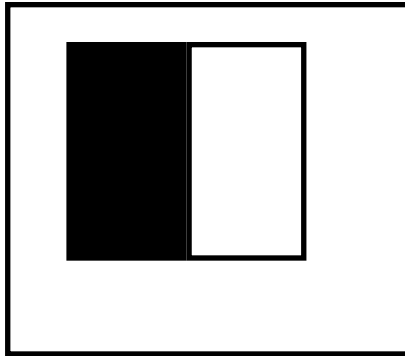A weak learner $h_{f, t, s}$ is described by:
  * feature f
  * threshold t
  * sign s (+1 or -1)

For an example x,
$$h_{f,t,s}(x) = 1, \text{if } sf(x) \geq t$$
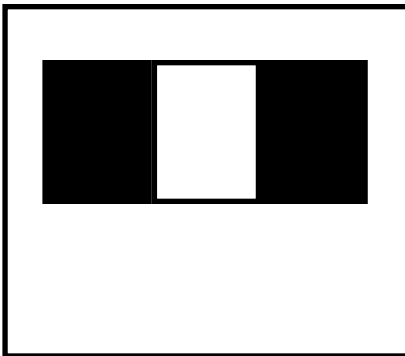$$= -1, \text{otherwise}$$
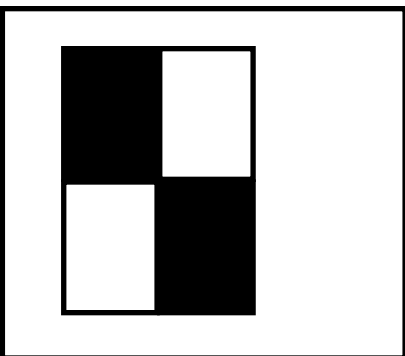
Viola-Jones: 3 Types of Features

1 Feature value = sum of pixel colors in black rectangle - sum of pixel colors in white rectangle

2 Feature value = sum of pixel colors in black rectangles - sum of pixel colors in white rectangle

3 Feature value = sum of pixel colors in black rectangles - sum of pixel colors in white rectangles
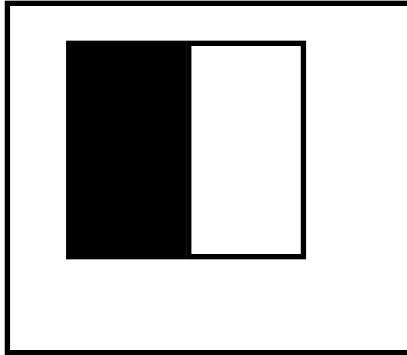
Viola-Jones Weak Learners

A weak learner $h_{f, t, s}$ is described by:
   * feature f (3 types of rectangular features)
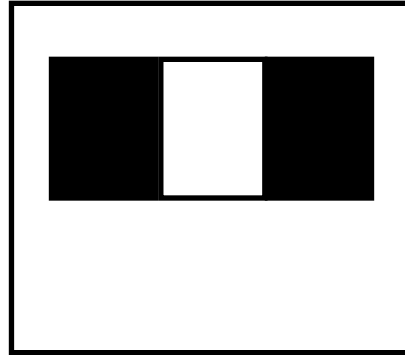   * threshold t
   * sign s (+1 or -1)

For an example x,
$$h_{f,t,s}(x) = 1, \text{if } sf(x) \geq t$$
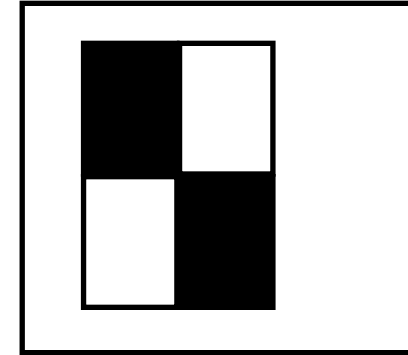$$= -1, \text{otherwise}$$

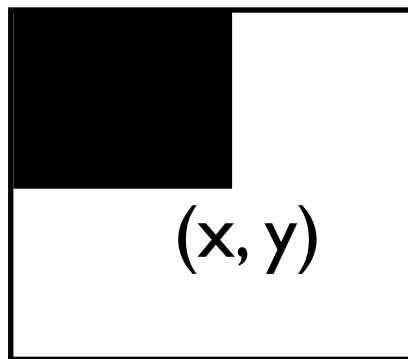# Viola-Jones: Computing the Features

1   2   3

Viola-Jones: Computing the Features

Precompute and store the values s(x,y) for each (x, y):

$s(x, y)$ = sum of pixel colors in the black rectangle

Now each feature can be computed from adding/subtracting a constant number of s(x,y)'s

Viola-Jones: Procedure

Given training set $S = \{(x_1, y_1), ..., (x_n, y_n)\}$, y in $\{-1, 1\}$

For $t = 1, ..., T$

    Construct distribution D_t on the examples

    Find weak learner h_t which has small error $err_{Dt}(h_t)$ wrt D_t

Output final classifier

Weak learning procedure: Find the feature f, sign s, and threshold t for which the error of $h_{f,t,s}$ on D_t is minimum

Viola-Jones: Procedure

Given training set S = {(x_1, y_1), ..., (x_n, y_n)}, y in {-1, 1}

For t = 1, ..., T

    Construct distribution D_t on the examples

    Find weak learner h_t which has small error $err_{Dt}(h_t)$ wrt D_t

Output final classifier

Initially, $D_1(i)$ = 1/n, for all i (uniform)

Given D_t and h_t:

$$D_{t+1}(i) = \frac{D_t(i)}{Z_t} exp(-\alpha_t y_i h_t(x_i))$$

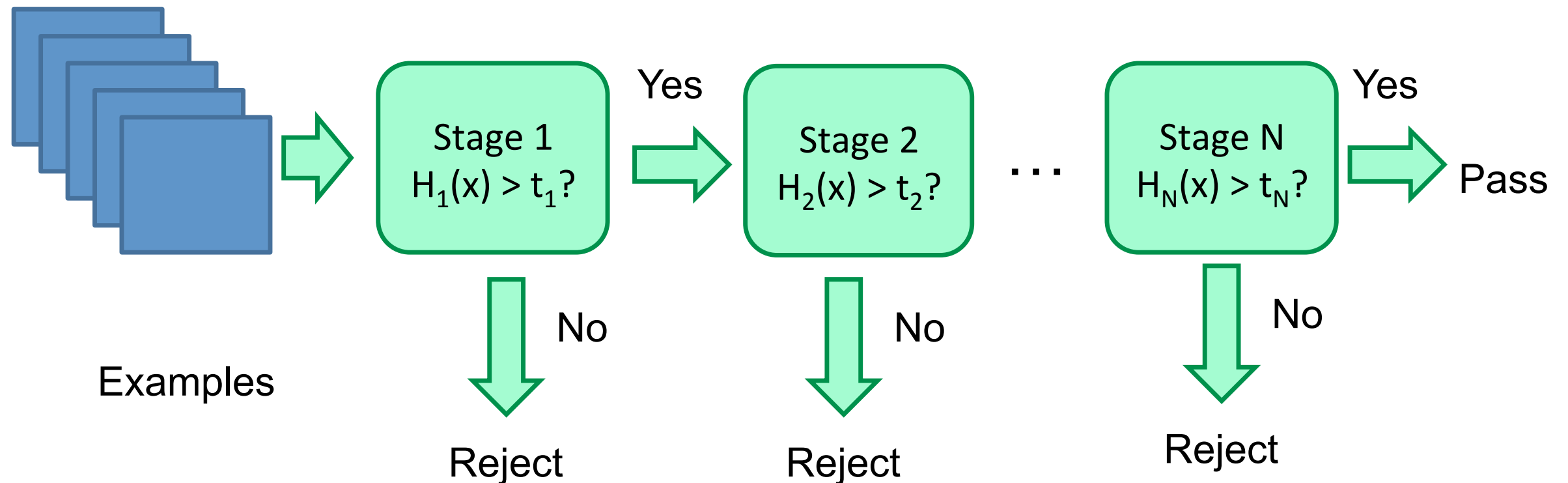Final classifier: $sign(\sum_{t=1}^{T} \alpha_t h_t(x))$

where:

$$\alpha_t = \frac{1}{2} \ln \left(\frac{1 - err_{D_t}(h_t)}{err_{D_t}(h_t)} \right)$$

Viola and Jones: Some Results

Cascades for Fast Classification

Choose thresholds for low false negative rates

Fast classifiers earlier in cascade, slower classifiers later

Most examples don't get to the later stages, so system is fast on an average