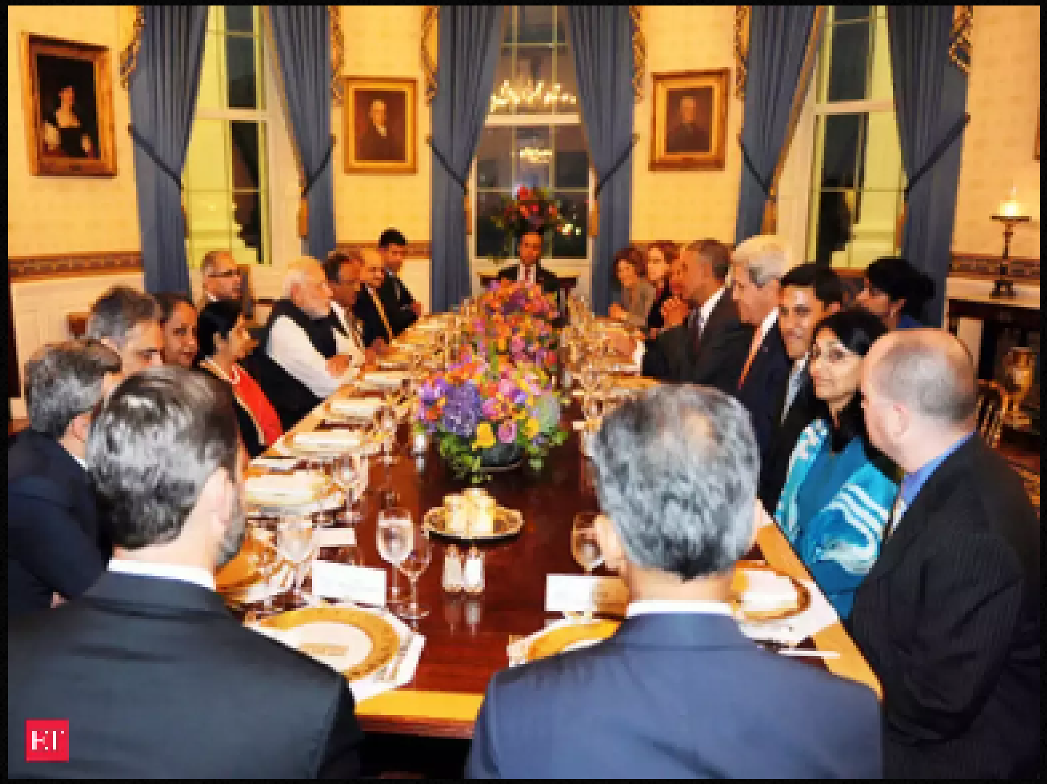
Face Detection using Viola-Jones

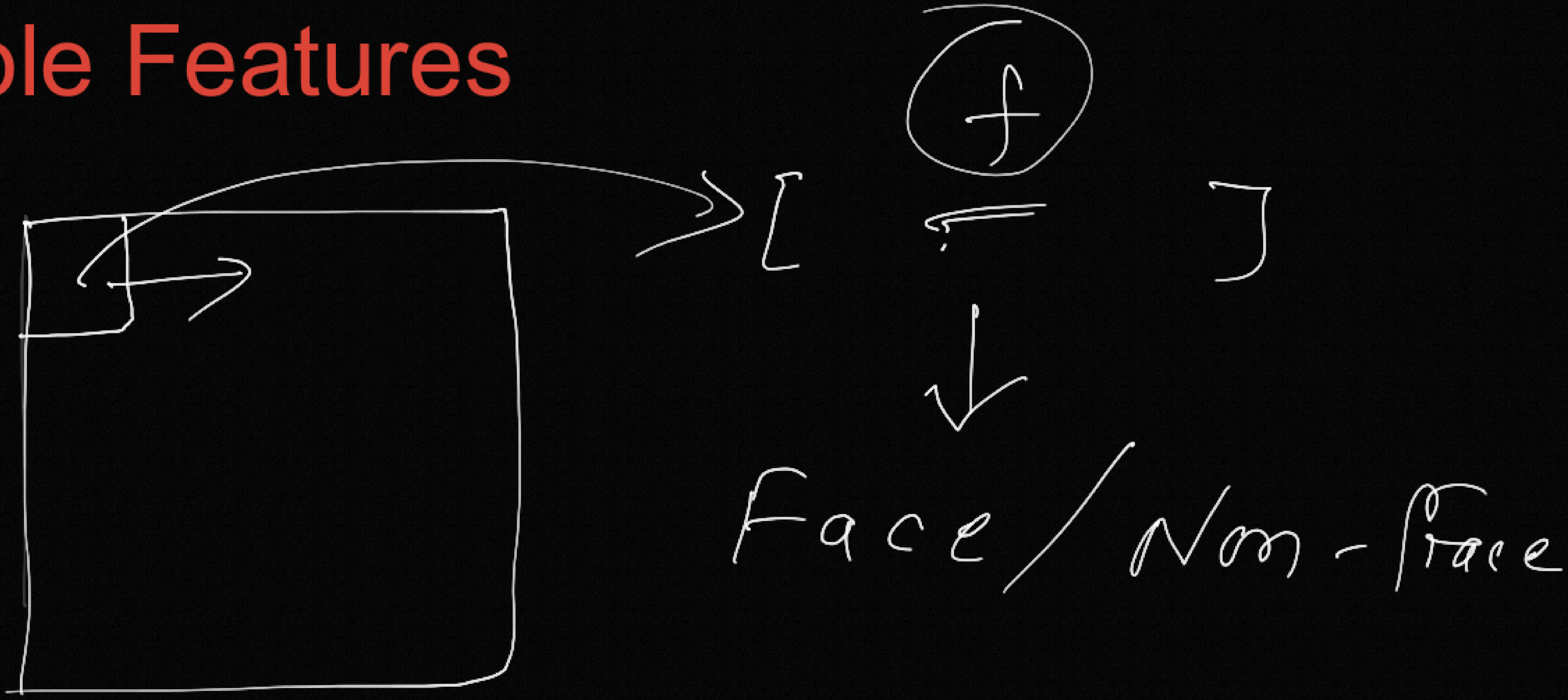
Face Detection Problem

Face Detection Problem

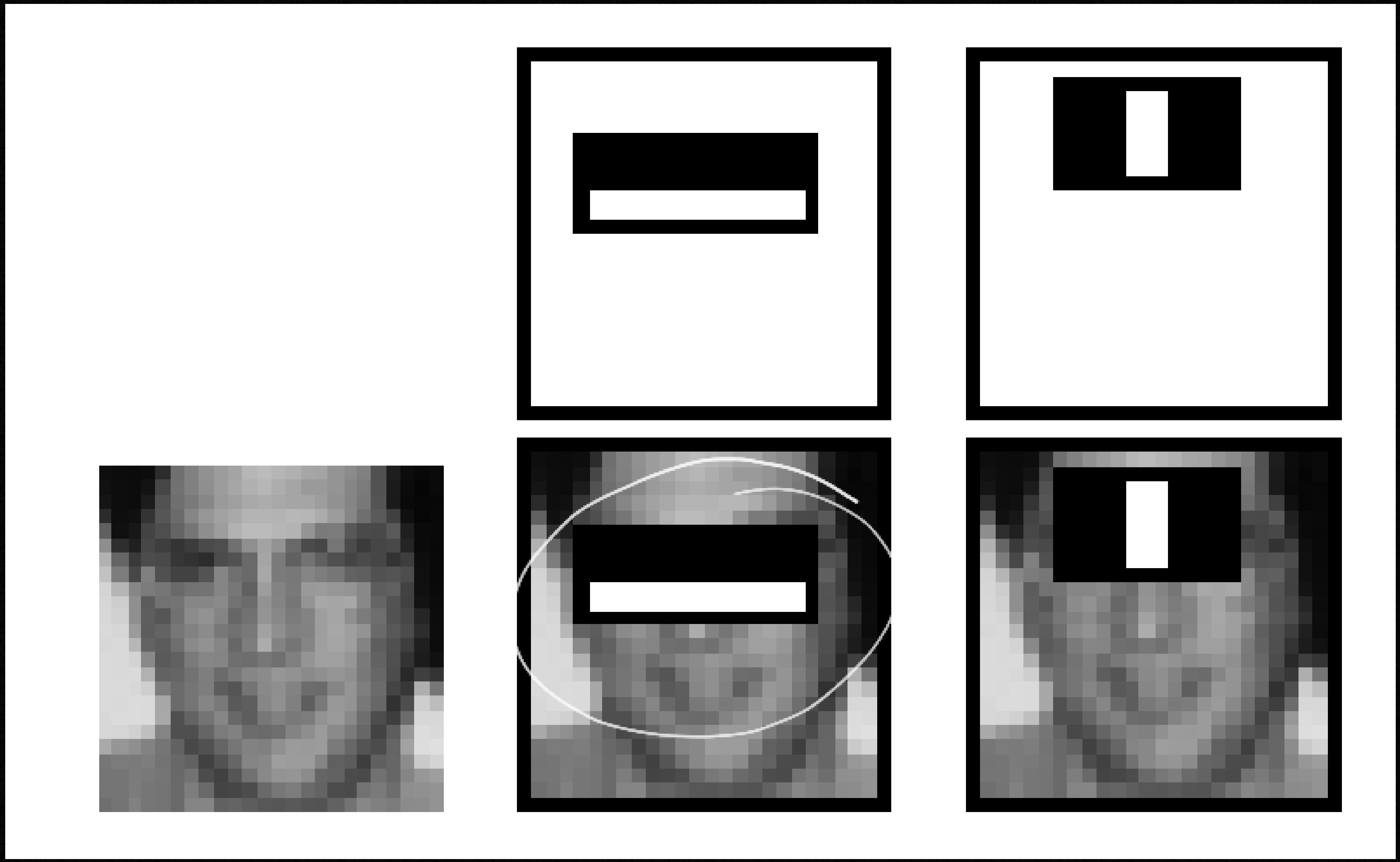
Why face detection is hard?



Plausible Features



Haar Features



HA

-1 Black

+1 White

W	B
B	W

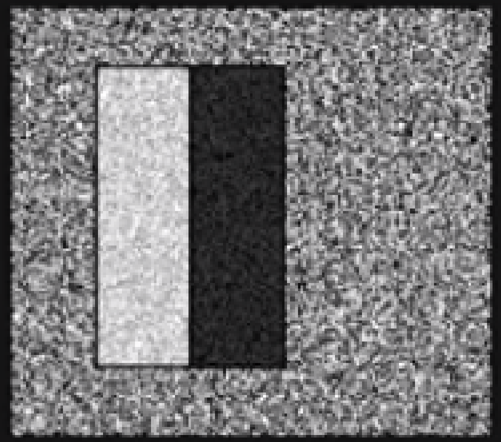
$$V_A[i,j] = \sum_m \sum_n I(m-i, n-j) \cdot H_A(m,n)$$

= Summation of bottom region − Summation of top region

= $\sum$ White area − $\sum$ Black area.

$\boxed{\text{Integral Image}}$

$V_A = 64$



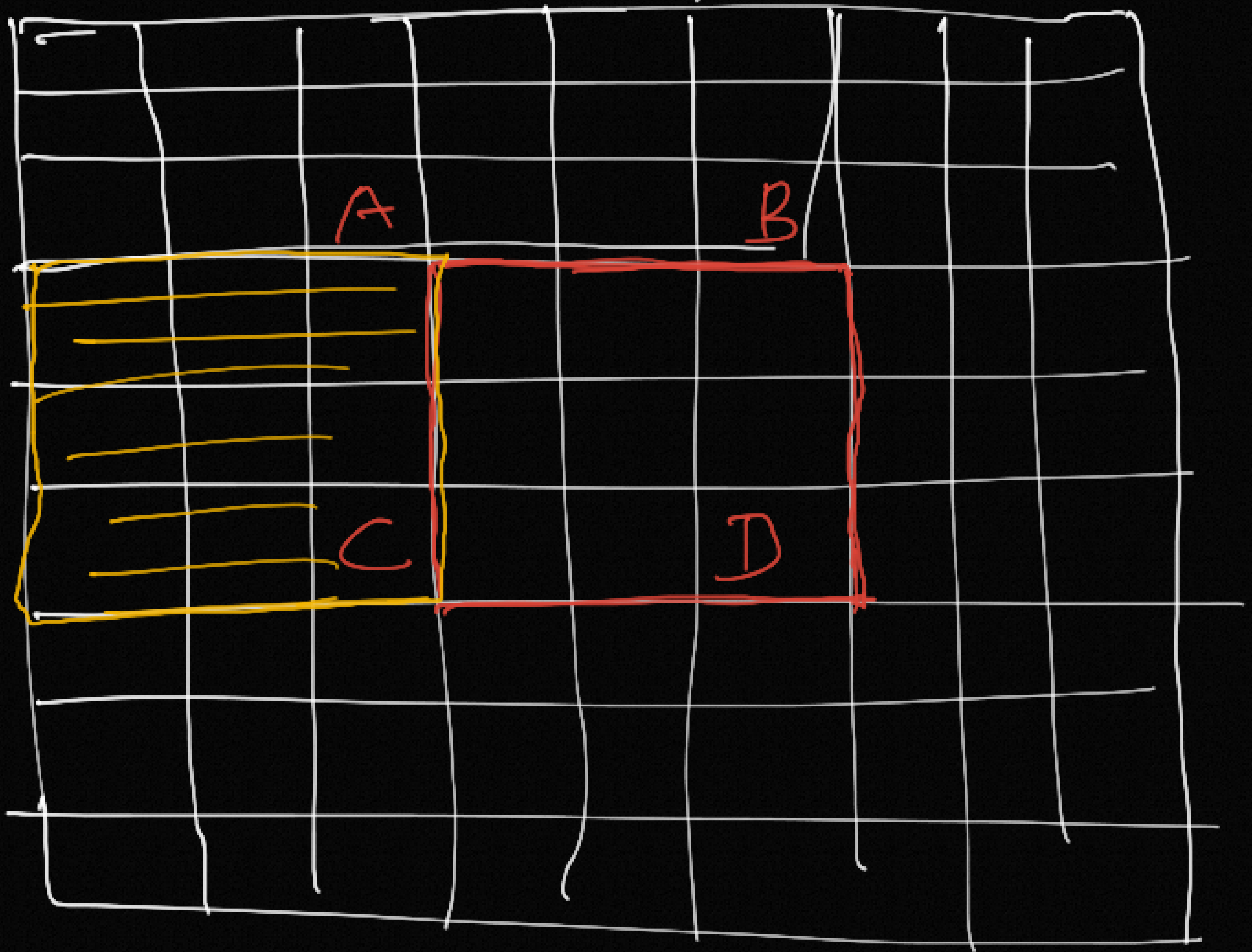
$V_A \approx 0$

$V_A = 16$

$V_A = -127$

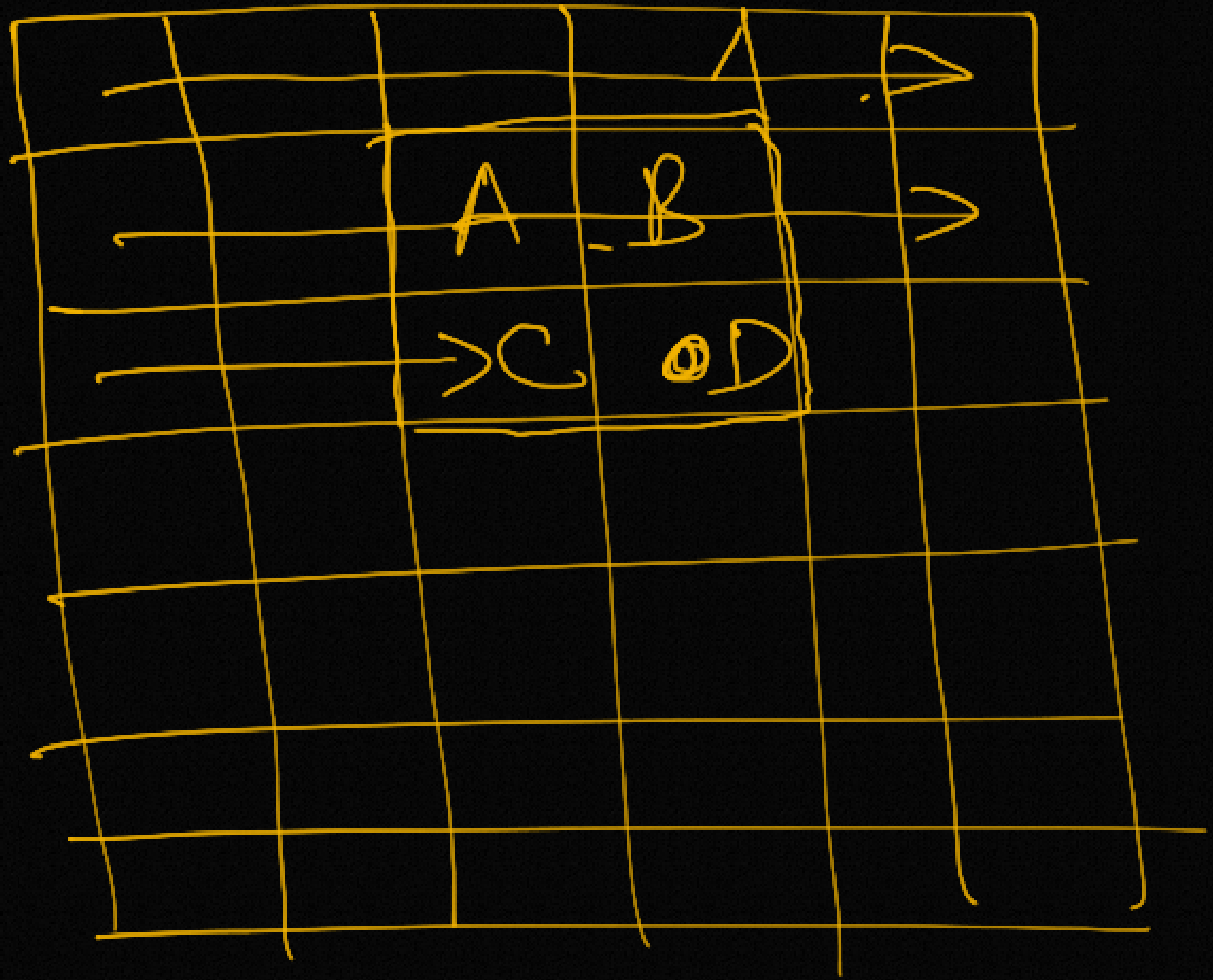
Integral Image

II



Summation inside red region

$= D - C - B + A$



$$II_D = II_C + II_B - II_A + I_D$$

SVM for face Vs non-face

Eigenfaces (1991)

$I = \{ \square_{100 \times 100}, \square, \square, \square \cdots \}$

Training Images $= \{ \Gamma_1, \Gamma_2, \cdots \Gamma_M \}$

$N \times N = N^2 \times 1$

$\Psi = \frac{1}{M} \sum_{i=1}^{M} \Gamma_i \leftarrow$ Mean face

Covariance Matrix

$$C = \frac{1}{m}\sum_{i=1}^{m} (\Gamma_i - \Psi)(\Gamma_i - \Psi)^T$$

$$= \frac{1}{m}\begin{bmatrix} \Phi_1 & \Phi_2 & \cdots & \Phi_m \end{bmatrix} \begin{bmatrix} \Phi_1 \\ \Phi_2 \\ \vdots \\ \Phi_M \end{bmatrix}$$

$N^2 \times M$

$\phi_i = \Gamma_i - \Psi$

$M \times N^2$

$$= \frac{1}{m} A A^T$$

$N^2 \gg M$

10000 100

$A^T A \longrightarrow$ Eigen value

$\underset{M \times N^2}{A^T} \; \underset{N^2 \times M}{A}$

Suppose v_i is i^{th} eigen vector of $A^T A$.

$$A^T A \underset{\hookrightarrow M \times 1}{v_i} = \lambda_i v_i$$

$\lambda_i \to i^{th}$ eigen value

$$A A^T \underbrace{A v_i}_{N^2 \times M \times M \times 1} = \lambda_i \, A v_i$$

$$\Rightarrow A A^T u_i = \lambda_i u_i \qquad u_i = A v_i$$

We obtained eigen vectors of Cov. Matrix

$\{\lambda_1, \lambda_2 \cdots \lambda_k \cdots \lambda_m\}$ → Sorted

$\{v_1, u_2 \cdots v_k \cdots v_m\}$ → eigen vector in ~~order~~ to sorted eigen values.

Test time

$$\omega_i = \underbrace{U_i^T}_{1 \times N^2} \underbrace{(\Gamma - \Psi)}_{N^2 \times 1}$$

$$\Omega = [\omega_1, \omega_2 \cdots \omega_K]$$

$$\Gamma^R = \sum_{i=1}^{K} w_i u_i$$