Hardware-software object tracking system using a moving camera

Digilent design contest 2019

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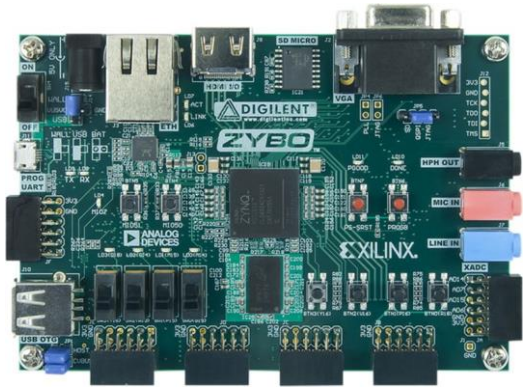
Object tracking

Frame 1

Frame 40

Frame 95

The idea



ZYBO

ARM

PC

Communication with FPGA

P regulator

TCP/IP loop

AXIS camera

FPGA logic

Communication with processor

Tracking algorithm

Visualization

Monitor

KLT tracking algorithm

A

$T_{\boldsymbol{d}=[d_x\ d_y]}$

B

$$min\ \varepsilon(\boldsymbol{d}) = \sum_{(x,y)\in ROI} \left(A(x,y) - B\left(x + d_x, y + d_y\right)\right)^2$$

KLT tracking algorithm

$$G \doteq \sum_{(x,y)\in ROI} \begin{bmatrix} {I_x}^2 & I_x I_y \\ I_x I_y & {I_y}^2 \end{bmatrix} \qquad \boldsymbol{d} \doteq \sum_{(x,y)\in ROI} \begin{bmatrix} \delta I\, I_x \\ \delta I\, I_y \end{bmatrix}$$

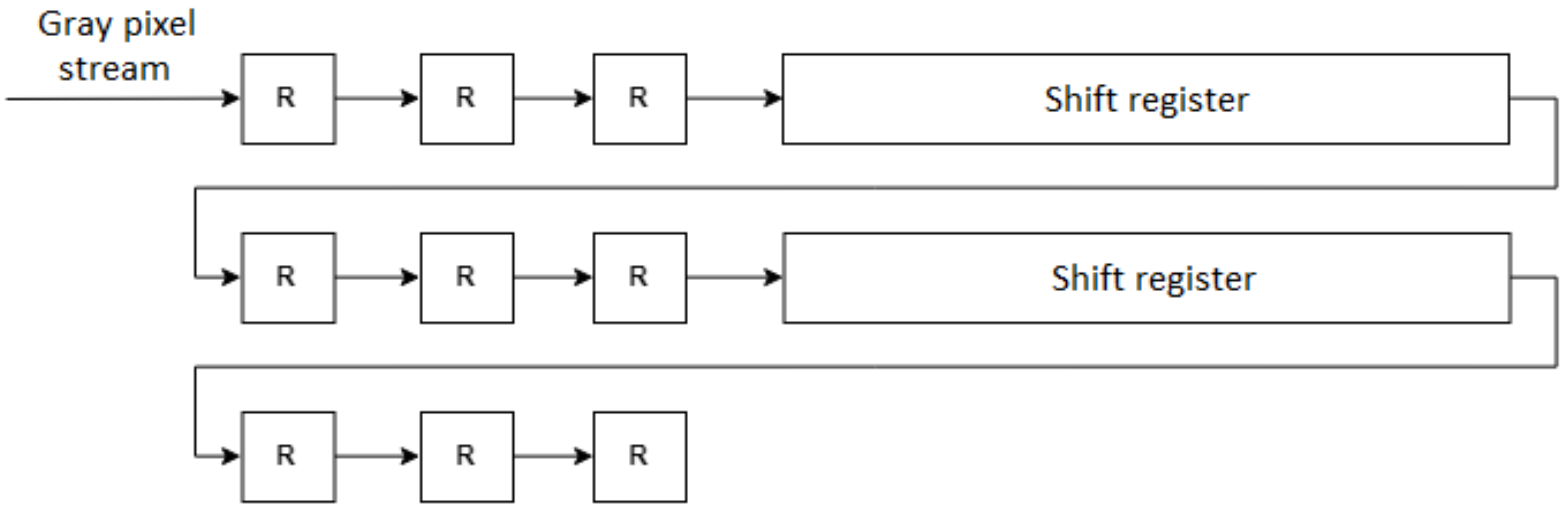
$$\delta I \doteq A(x,y) - B(x,y)$$

$$\begin{bmatrix} I_x \\ I_y \end{bmatrix} \doteq \nabla B$$

$$\boldsymbol{G\,d^* = b}$$

$$\boldsymbol{d^* = G^{-1} b}$$

How to get image derivative?

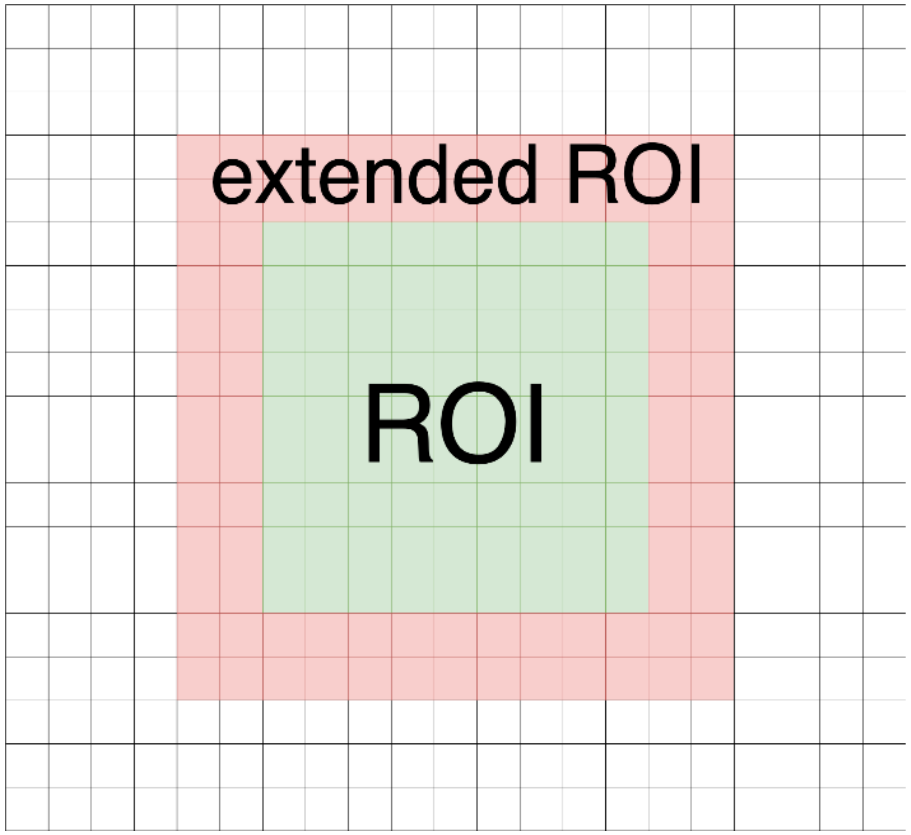


$$I_x(x,y) = \frac{img(x+1,y) - img(x-1,y)}{2}$$

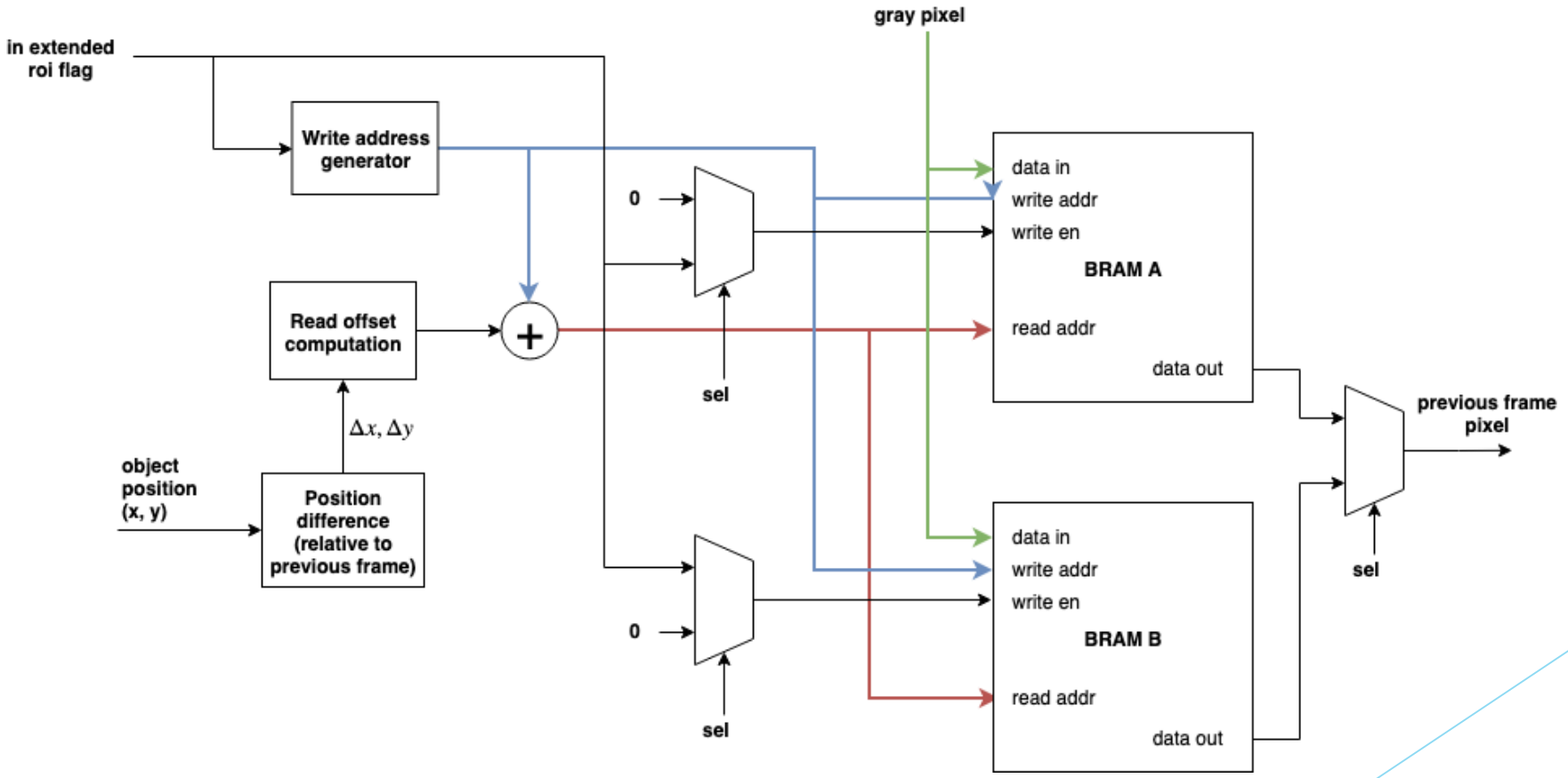
$$I_y(x,y) = \frac{img(x,y+1) - img(x,y-1)}{2}$$

How to get pixel from previous frame?

Let’s write ROI to the memory and read it in another frame



How to get pixel from previous frame?



How to solve linear equation system in FPGA?

$$G = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$

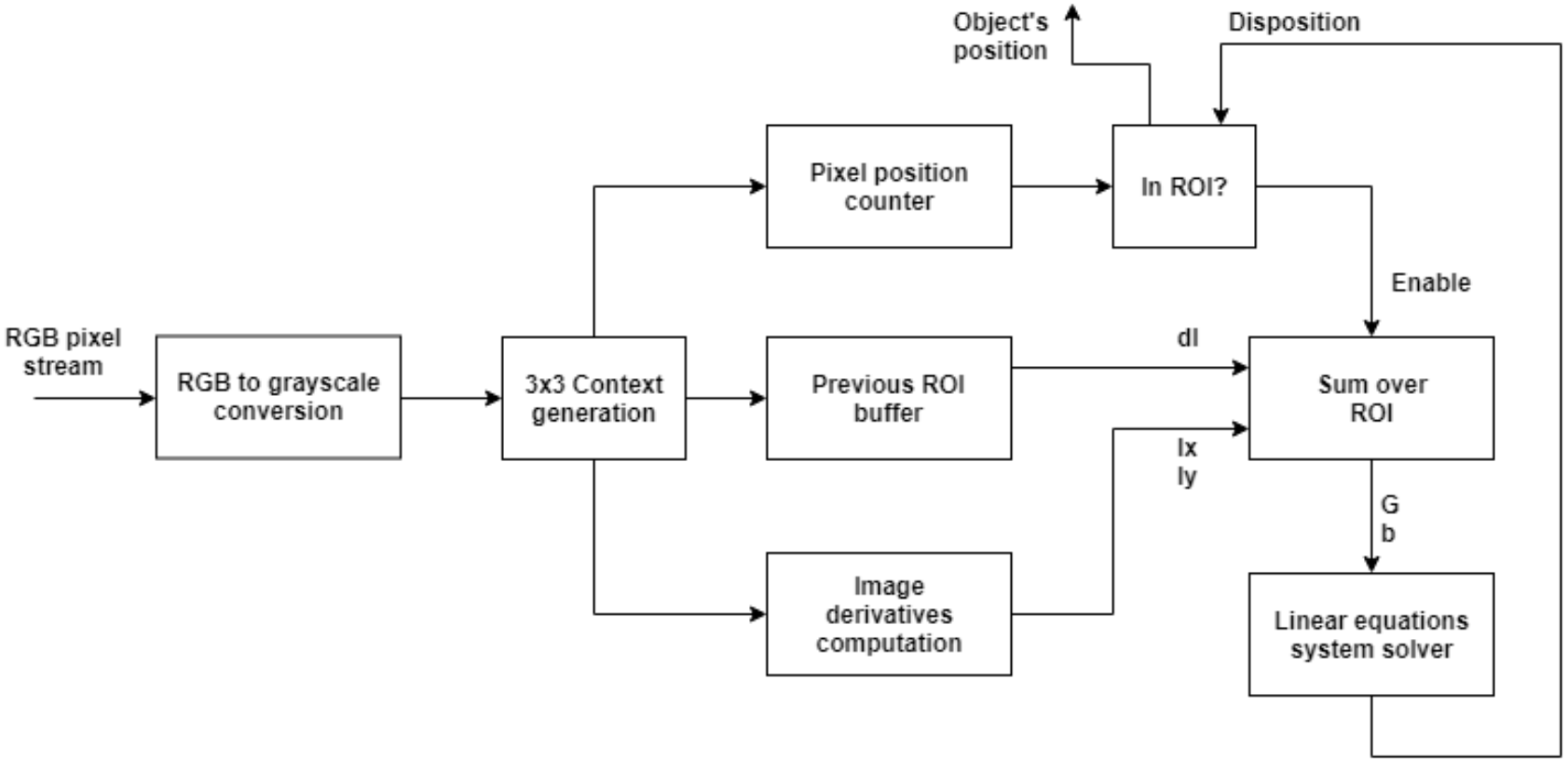
$$b = \begin{bmatrix} e \\ f \end{bmatrix}$$

The solution $d = [d_x \; d_y]^T$ is calculated using Cramer's rule:

$$d_x = \frac{ed - bf}{ad - bc}$$

$$d_y = \frac{af - ec}{ad - bc}$$

KLT tracker in FPGA



Multiscale (pyramidal) KLT

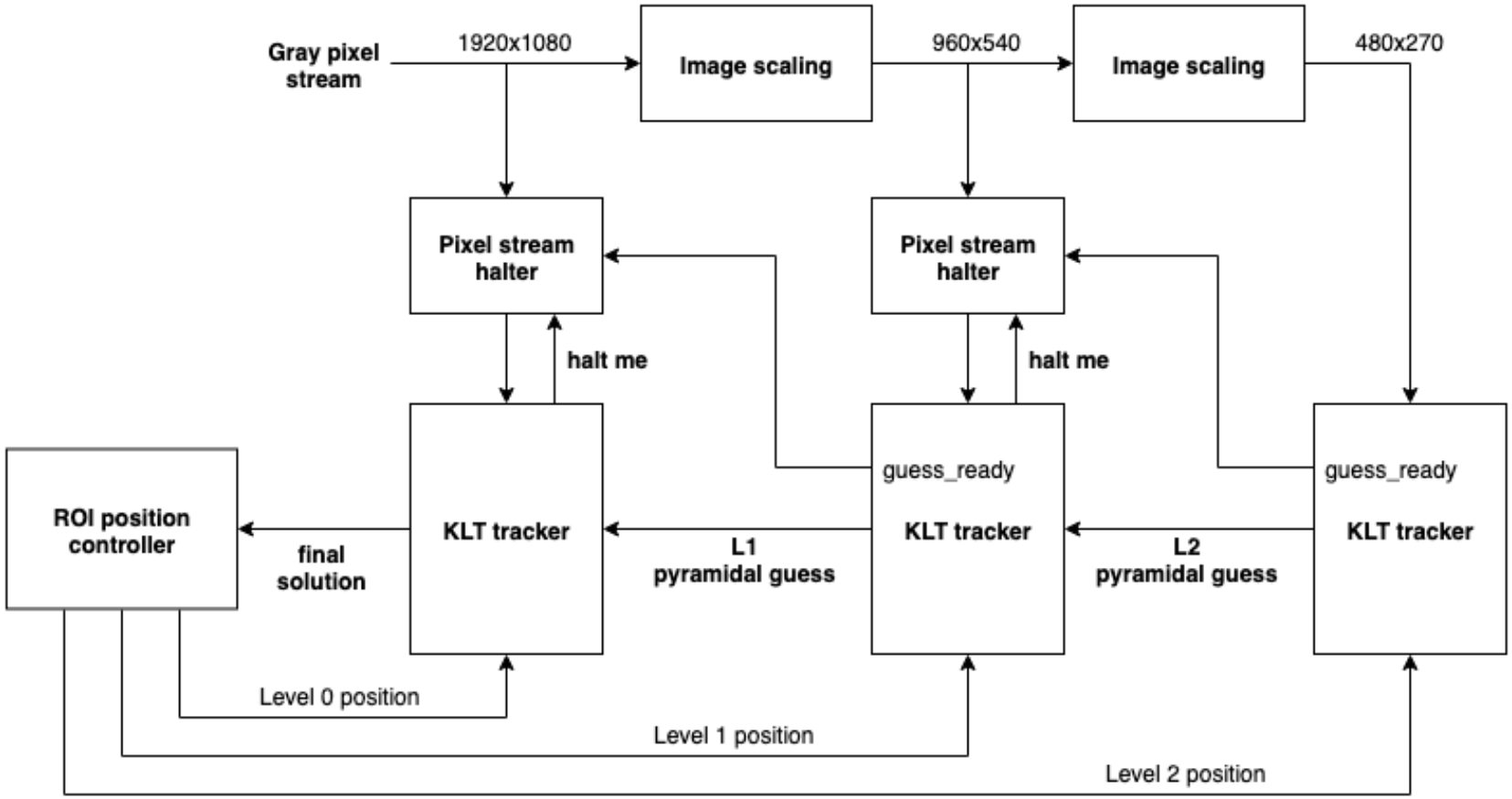


Image scaling

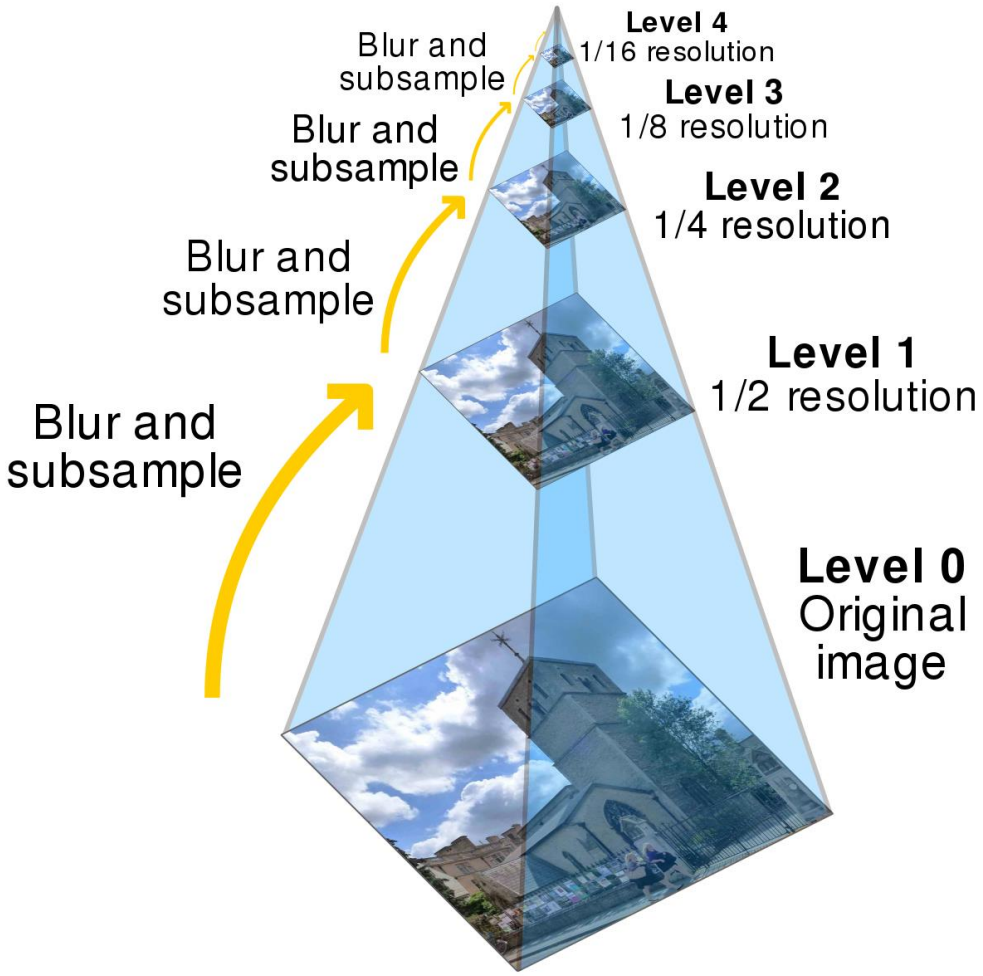
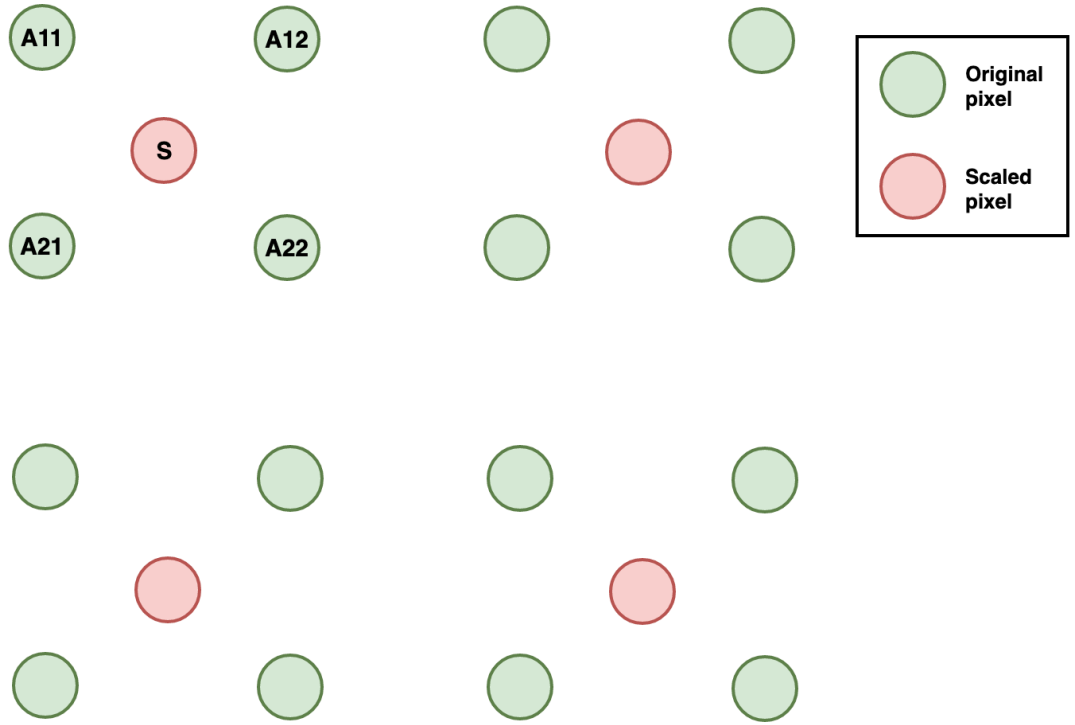


Image scaling



$$S = \frac{A_{11} + A_{12} + A_{21} + A_{22}}{4}$$

Image scaling