



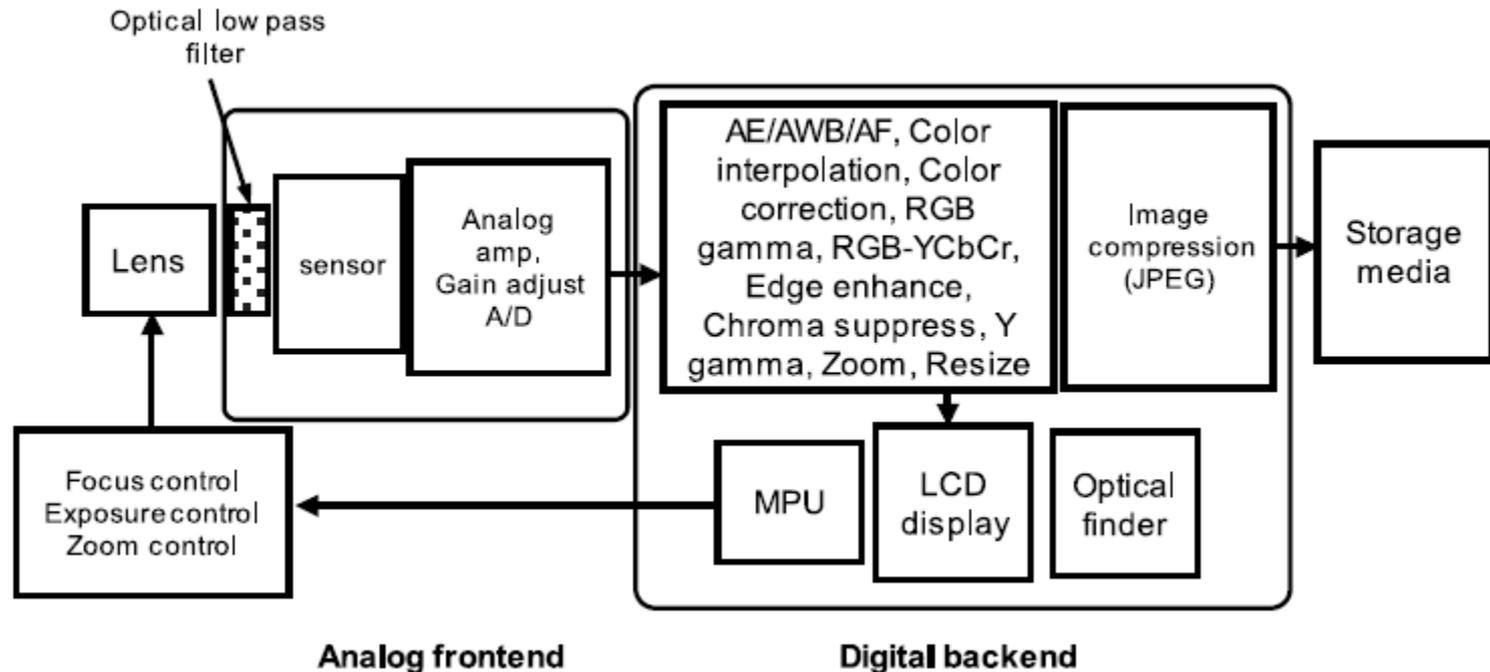
UiO : **Department of Informatics**
University of Oslo

INF5442 – Lecture 5
29-Sep-2014

Image Processing in Digital Cameras
Ref: Nakamura et.al, Ch-8



Digital camera and its typical configuration



Color correction

- Purpose: compensate for crosstalk between R-G-B pixels

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

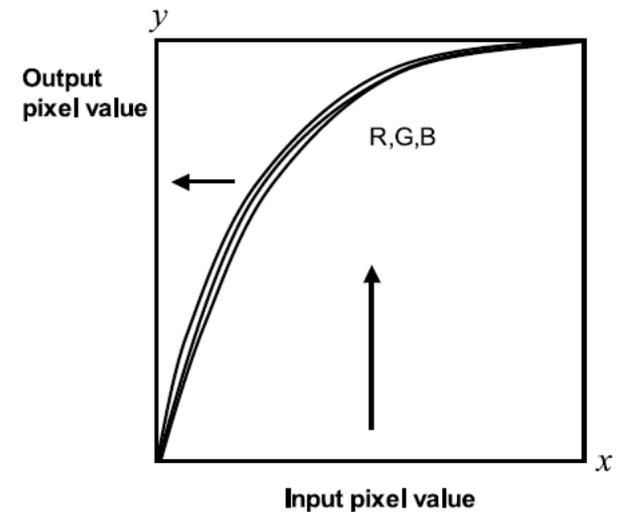
$$\sum_{i=1}^3 a_i = \sum_{i=1}^3 b_i = \sum_{i=1}^3 c_i = 1 .$$

Tone mapping / gamma curve

- Purpose: (i) compensate for non-linear response in CRT displays, (ii) data compression

$$y(x) = x^\gamma$$

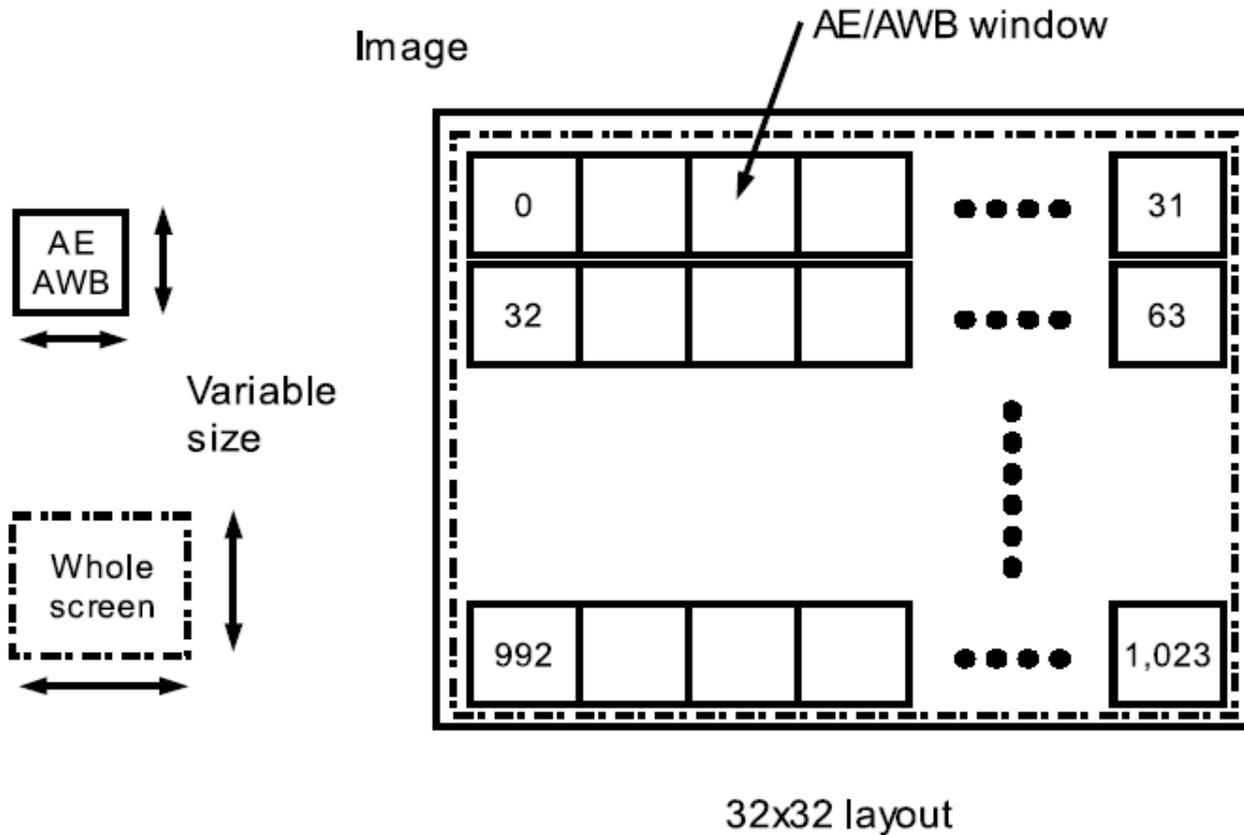
$\gamma \sim 0.45$ for CRT displays



Auto exposure control (AEC)

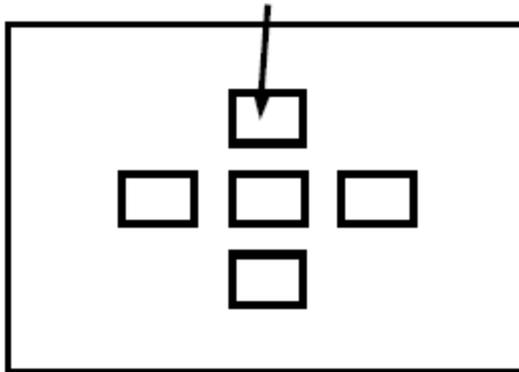
- Purpose: adjust the amount of incident light on the sensor so as to utilize its full dynamic range.
- Luminance (Y) used as input to AEC algorithm

AE/AWB windows



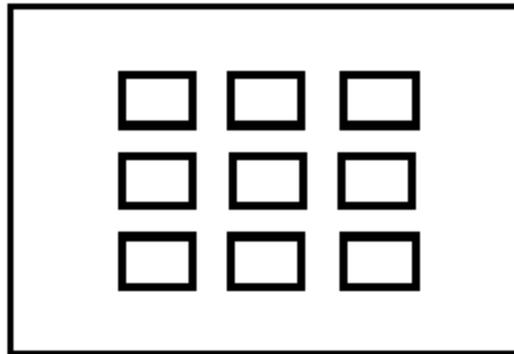
Auto-focus (AF) windows

Image AF window

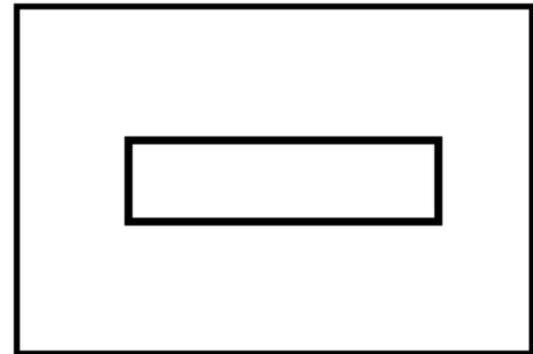


Five windows

Center focus



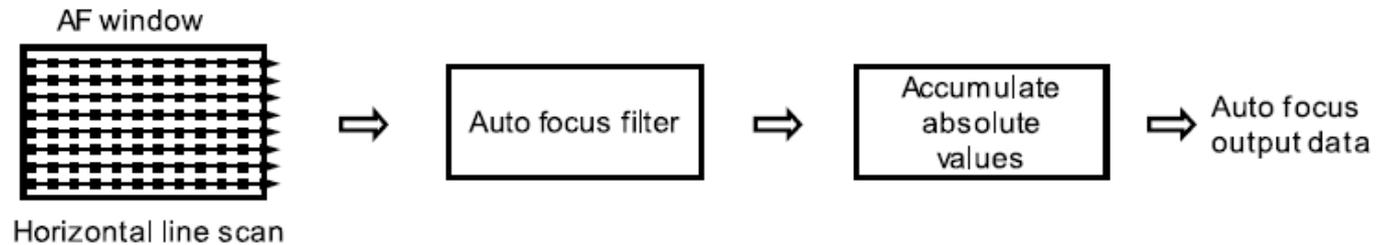
3x3 windows



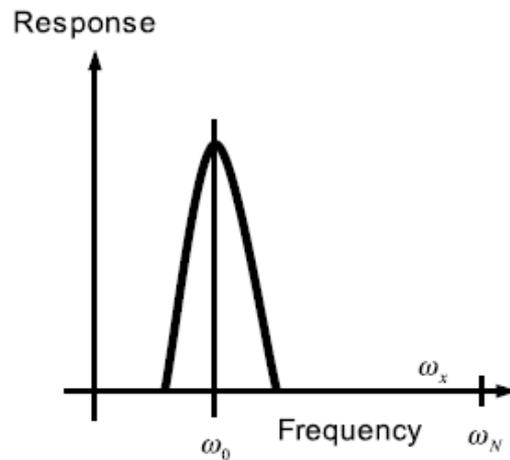
Single window

Fast response

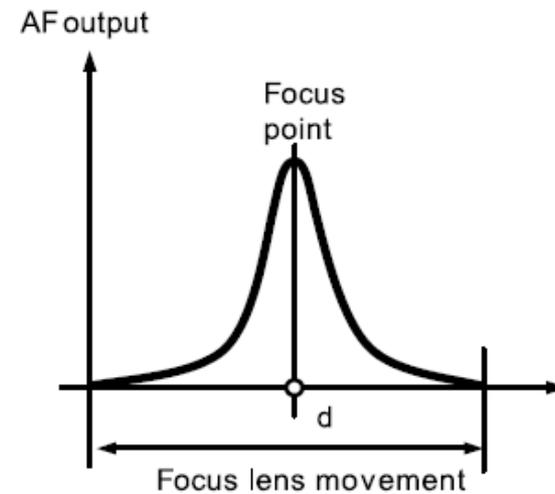
Auto-focus operation



(a) Auto focus operation for an AF window



(b) Auto focus filter response

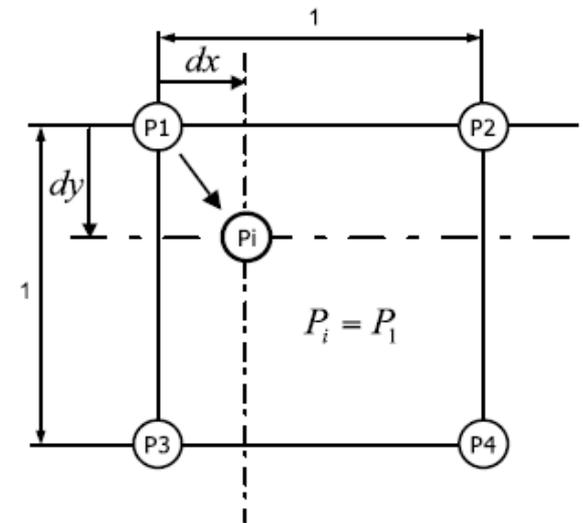


(c) Response of auto focus filter output

Electronic zoom (digital scaling)

- Purpose: Zoom in to enlarge selected region. Performed digitally, i.e. without use of zoom lens
- Inserts pixels between the original pixels, which are calculated by interpolation, $f(x)$.
 - Nearest neighbor
 - Linear interpolation
 - Bicubic interpolation

$$p(x) = \sum_i f(x - x_i) \cdot g(x_i)$$



Nearest neighbor interpolation

$$f(x) = 1 \quad 0 \leq |x| < 0.5$$

$$f(x) = 0 \quad 0.5 \leq |x| < 1$$

$$f(x) = 0 \quad 1 \leq |x|$$

- x : distance to pixel i
- $f(x)$: weighting factor

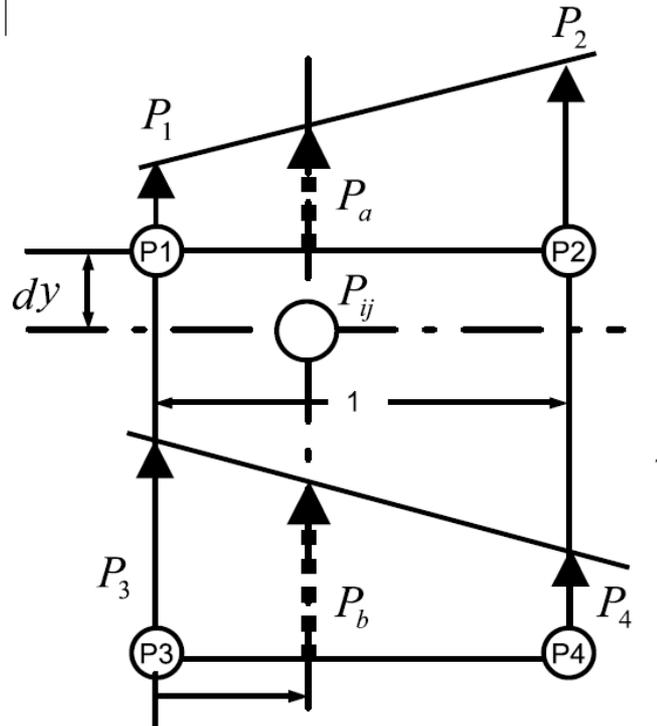
(Bi)Linear interpolation

Linear:

$$f(x) = 1 - x \quad 0 \leq |x| < 1$$

$$f(x) = 0 \quad 1 \leq |x|$$

Bi-Linear (x and y direction):



$$P_a = (1 - dx)P_1 + dx \cdot P_2$$

$$P_b = (1 - dx)P_3 + dx \cdot P_4$$

$$P_{ij} = (1 - dy)P_a + dy \cdot P_b$$

Bi-Cubic spline interpolation

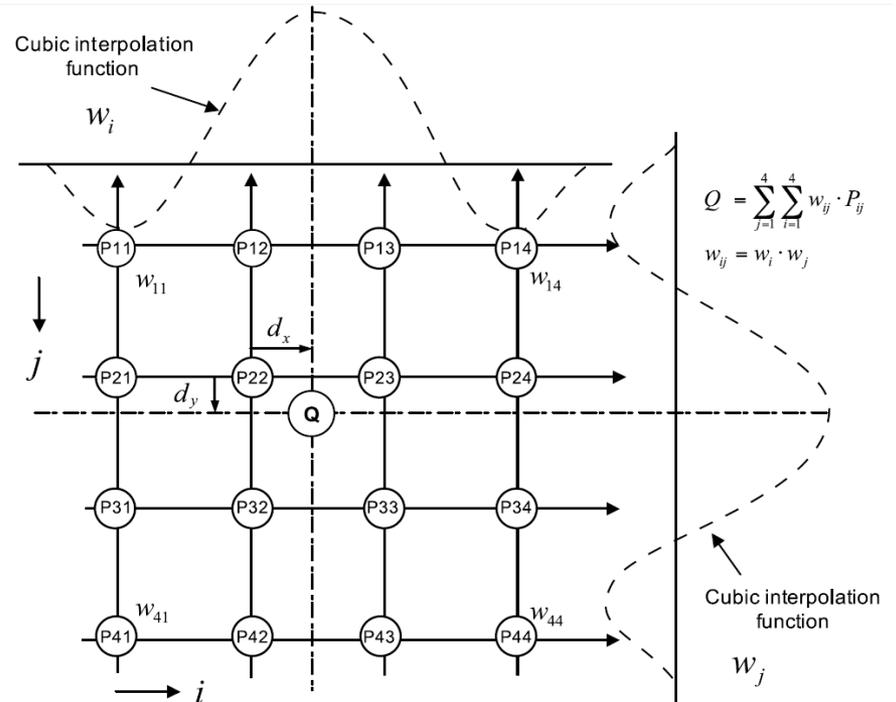
Cubic spline:

$$f(x) = (1-x)(1+x-x^2) \quad 0 \leq |x| < 1$$

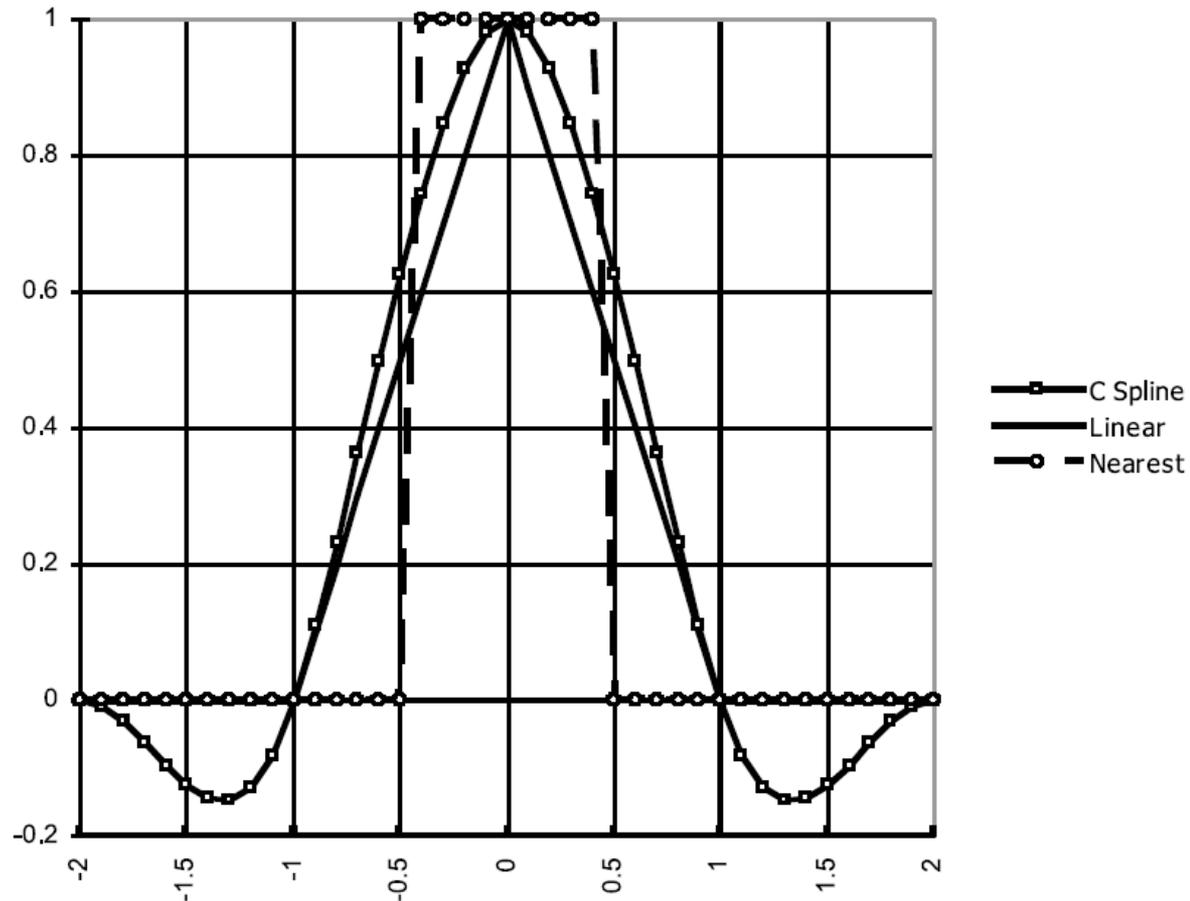
$$f(x) = (1-x)(2-x)^2 \quad 1 \leq |x| < 2$$

$$f(x) = 0 \quad 2 \leq |x|$$

Bi-cubic spline:



Comparison of interpolation functions

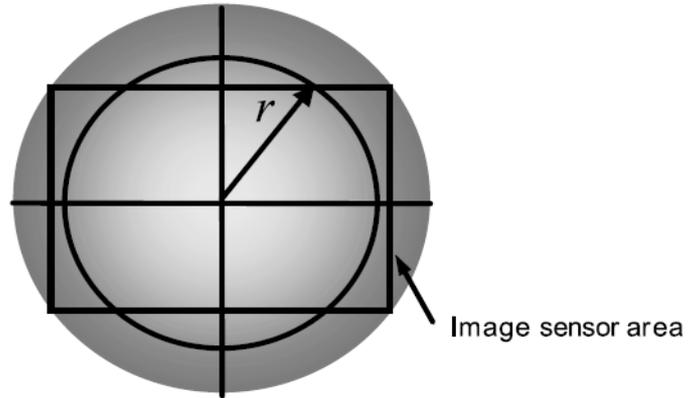


HW implementation cost

TABLE 8.4
Number of Multiply/Addition of Interpolation Functions

Interpolation function	Order	Multiply/add (one dimension)	Multiply/add (two dimensions)
Nearest neighbor	0	0	0
Linear	1	2	4
Cubic spline	3	4	16

Lens shading correction



(a) Shaded image

