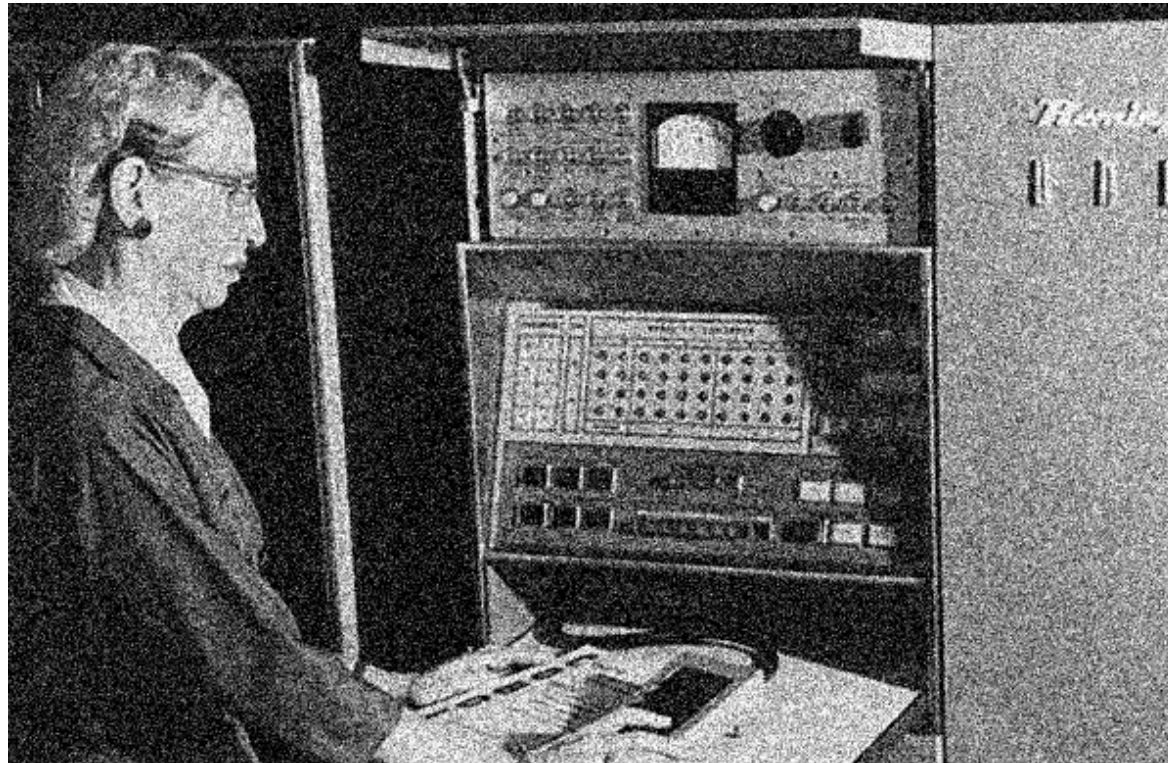


Image filtering: Outline

- Linear filtering and its properties
- Gaussian filters and their properties
- Nonlinear filtering: Median filtering

Different types of noise

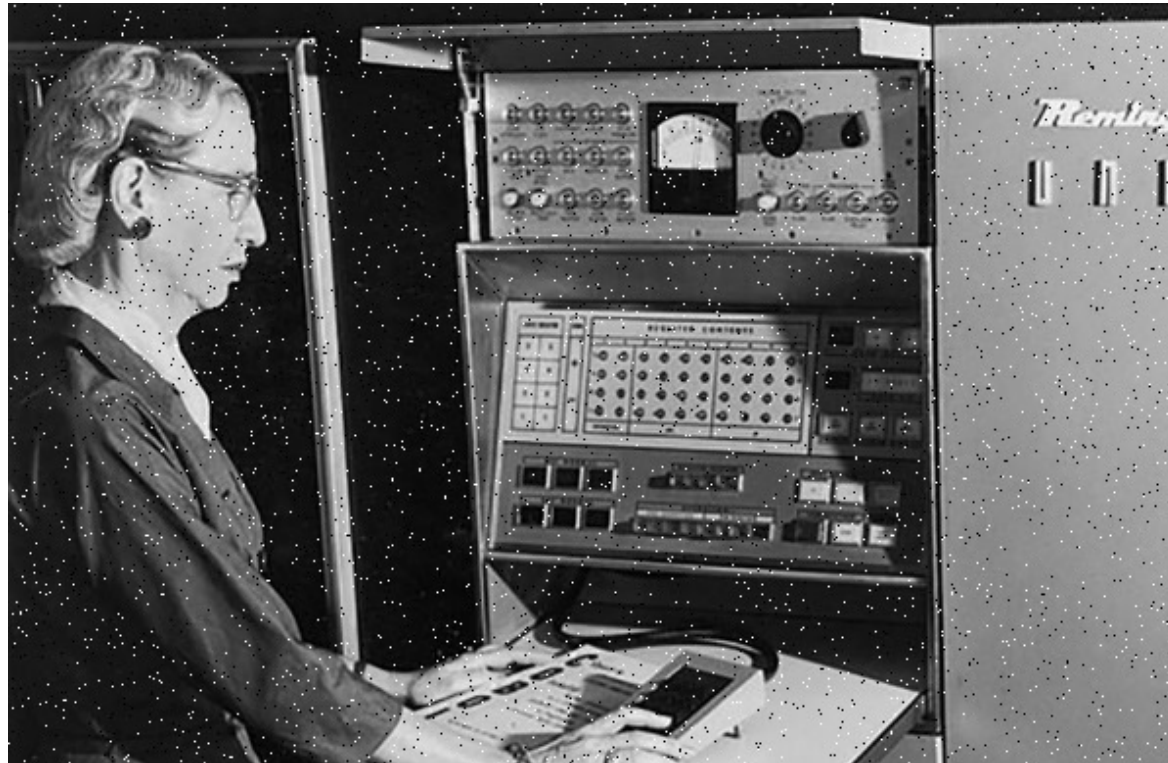
- Gaussian filtering is appropriate for *additive, zero-mean* noise (assuming nearby pixels share the same value)



Adapted from [D. Fouhey and J. Johnson](#)

Different types of noise

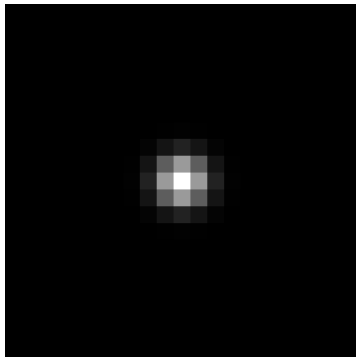
- What about *impulse* or *shot noise*, i.e., when some pixels are arbitrarily replaced by spurious values?



Adapted from [D. Fouhey and J. Johnson](#)

Where Gaussian filtering fails

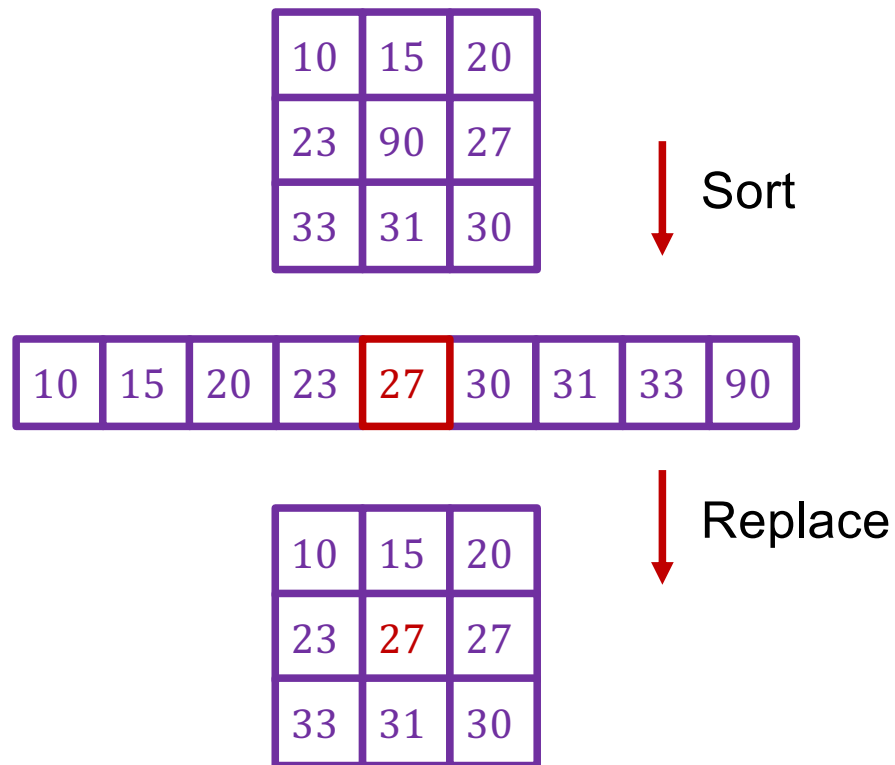
$$\sigma = 1$$



Adapted from [D. Fouhey and J. Johnson](#)

Alternative idea: Median filtering

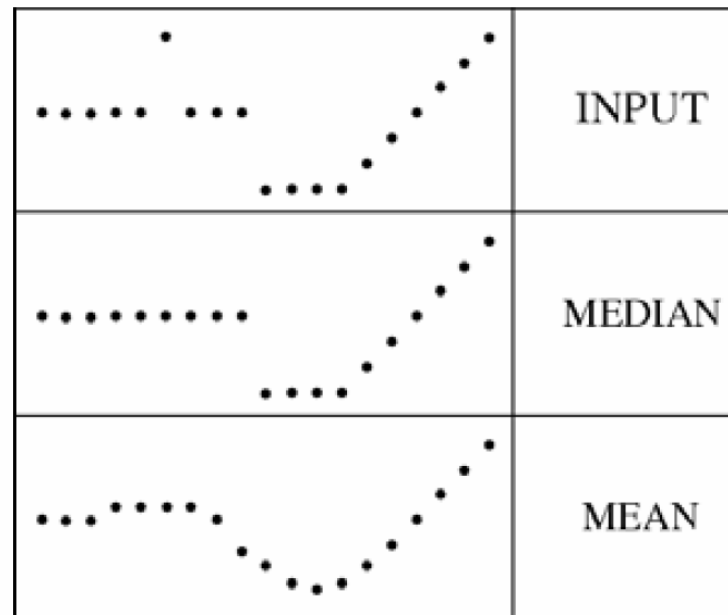
- A **median filter** operates over a window by selecting the median intensity in the window



Median filter

- What advantage does median filtering have over Gaussian filtering?
 - Robustness to outliers

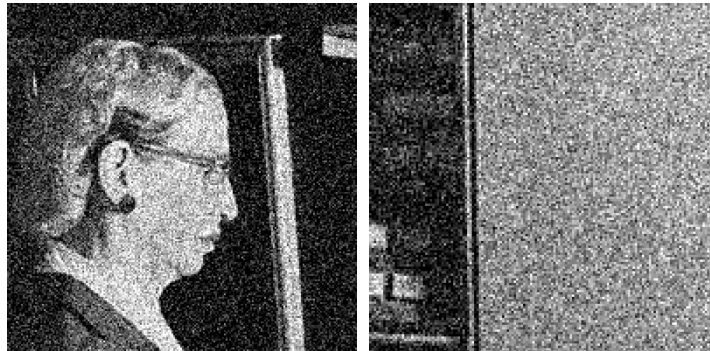
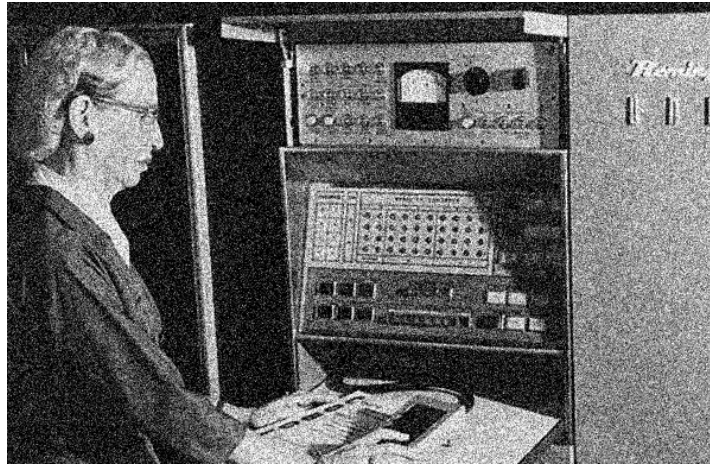
filters have width 5 :



Source: K. Grauman

Applying median filter

Input image
(no filter)



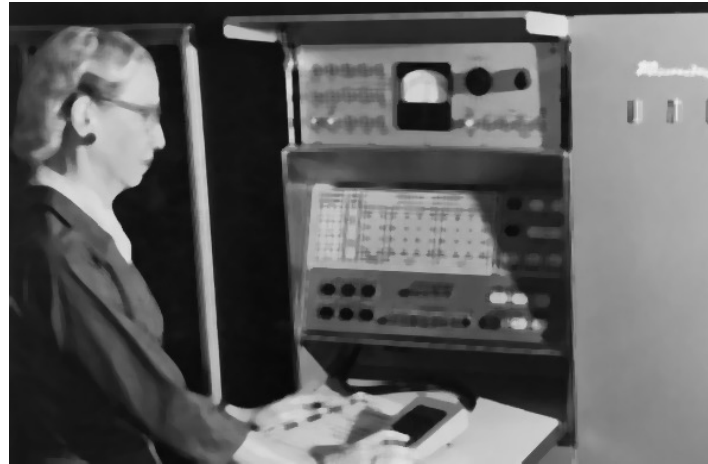
Applying median filter

median
filter
(width = 3)



Applying median filter

median
filter
(width = 7)



Is median filtering linear?

Is median filtering linear?

$$\begin{array}{ccccc} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 2 \\ 2 & 2 & 2 \end{bmatrix} & + & \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} & = & \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 2 \\ 2 & 2 & 2 \end{bmatrix} \\ \text{median} & & & & \\ \text{filter} & \downarrow & & \downarrow & \downarrow \\ & 1 & + & 0 & \neq & 2 \end{array}$$

Image filtering: Outline

- Linear filtering and its properties
- Gaussian filters and their properties
- Nonlinear filtering: Median filtering
- Fun filtering application: Hybrid images

Application: Hybrid images



A. Oliva, A. Torralba, P.G. Schyns,
[Hybrid Images](#), SIGGRAPH 2006

Recall: Sharpening



-



=



+ α



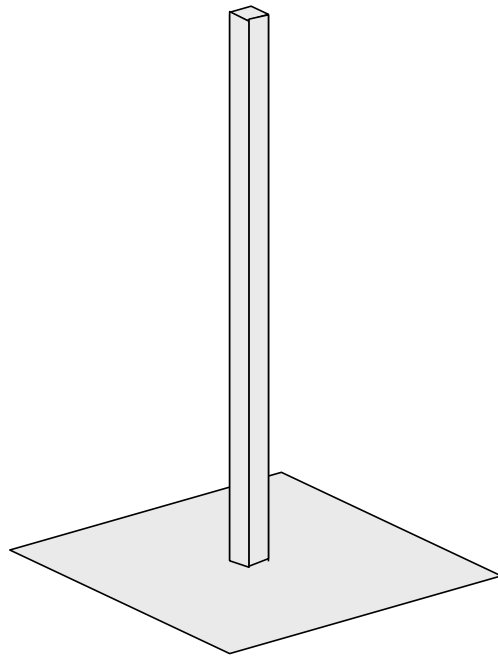
=



“Detail” filter

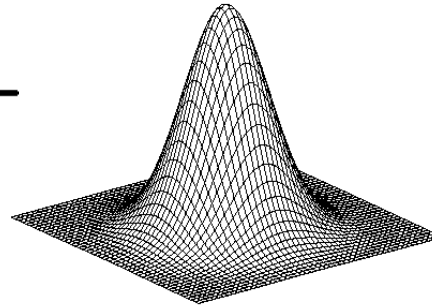
$$I - I * g = I * (e - g)$$

↑
unit impulse
(identity)



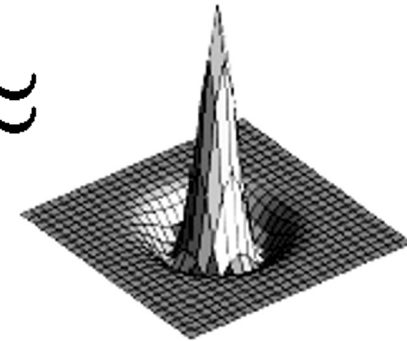
unit impulse

—



Gaussian

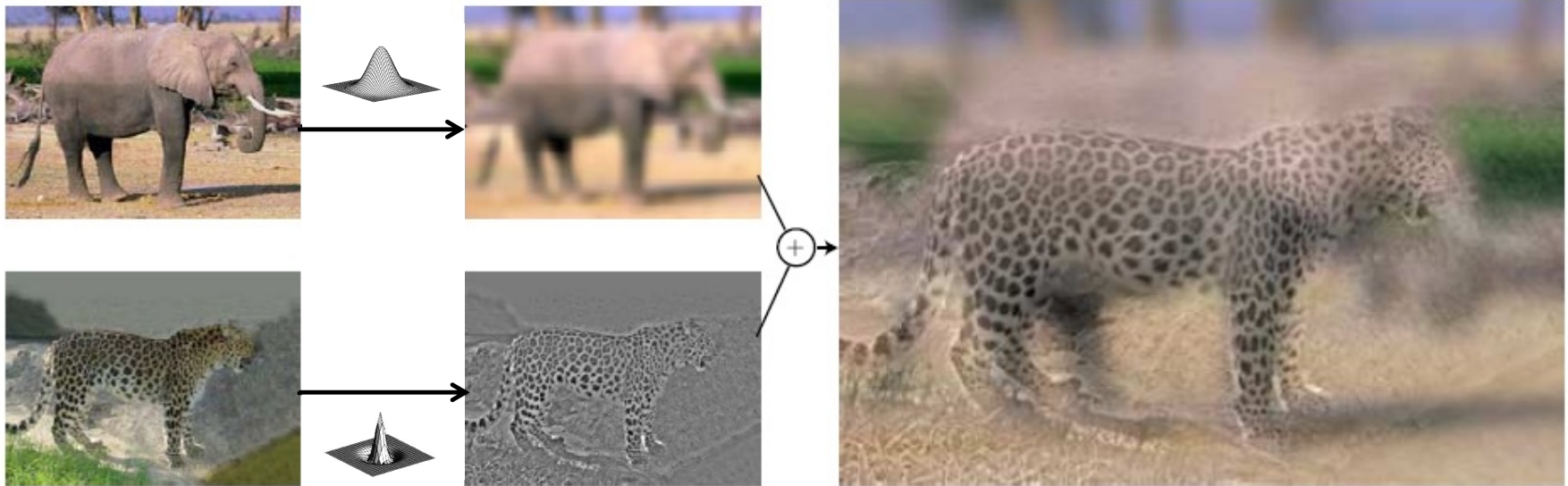
≈



Laplacian of Gaussian

Application: Hybrid images

Gaussian filter



Laplacian filter

Application: Hybrid images

Changing expression



SIGGRAPH2006

Sad



Surprised

