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R5: Read chapter 3 from the text book

Section 3.1

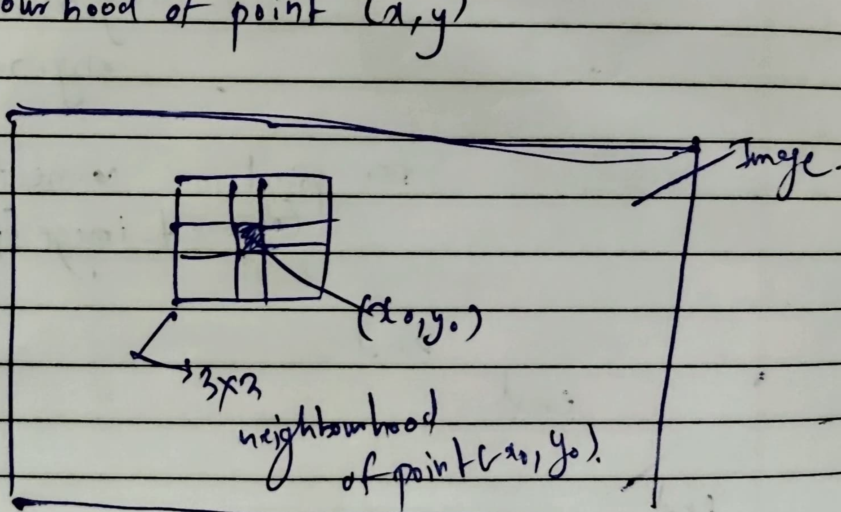
* spatial domain → image plane
* Spatial domain techniques operate directly on the pixels of an image.

The basics of intensity transformation and spatial filtering

$$g(x,y) = T\left[f(x,y)\right] \rightarrow (1)$$

$f(x,y) \rightarrow$ input image
$g(x,y) \rightarrow$ output image

T is an operator on f defined over a neighbourhood of point (x,y)



* ~~Eqn(1)~~ ~~otherwise~~ ~~it~~
* we move the center of the neighbourhood ~~pix~~ from pixel to pixel and apply the operator T to the pixels in the neighbourhood

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to yield an output value at that location (x_0, y_0)

Example

$(x_0, y_0) = (100, 150)$

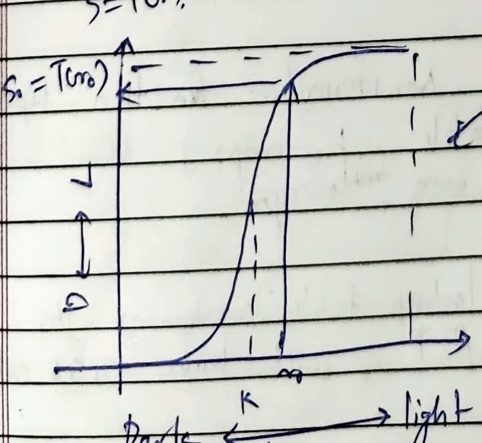
T → (average intensity of the pixels in the neighbourhood)

$g(100, 150) = T[f(100, 150)]$

sum of $f(100, 150)$ and its 8 neighbour-hood divided by 9.

- Smallest possible neighbourhood is of size 1×1
- In this case g depends on value of single point (x, y)

$s = T(r)$ → (T becomes intensity transformation function)



(contrast stretching)

- Darkening the intensity values below k
- Brightening the intensity values above k

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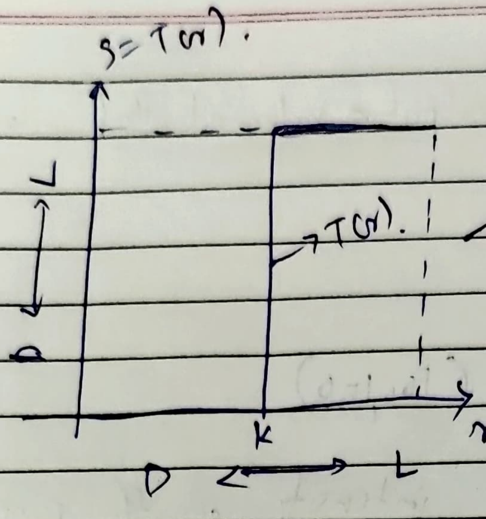


(thresholding function).

T(r) produces two level binary image.

<u>Enchancement</u> → It is the process of manipulating an image so that the result is more suitable than the original for a specific application.
& It is most visually appealing area of image processing.

<u>3.2</u> Some basic intensity transformation function

- Values of intensity transformation function typically are stored in table, the mappings from r to s are implemented via table lookups.

8-bit image, a lookup table containing the values of T will have 256 entries.

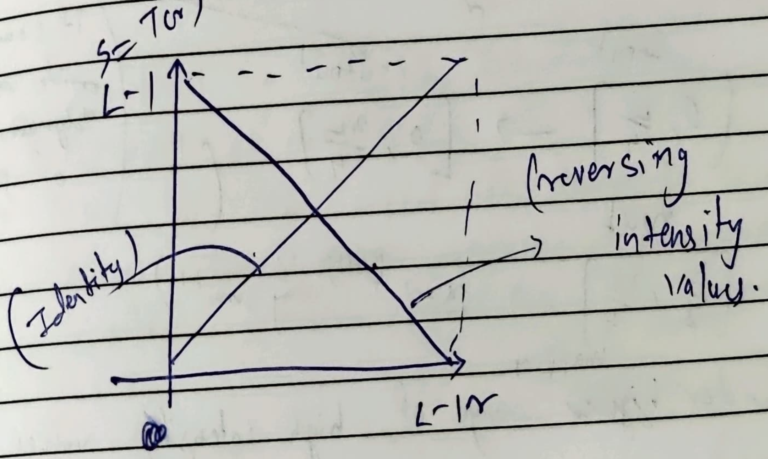
functions :-

- linear (negative and identity transformation)
- logarithmic (log and inverse-log transformations)
- power-law (nth power and nth root transformation)

image negatives

negative of an image with intensity levels in the range [0, L-1] is obtained using negative transformation :

$$s = L - 1 - r$$



- Uses
- It is used in enhancing white or gray details embedded in dark regions of an image. (when black area is dominant),
- Breast cancer can be detected or like tissues will be more finely detailed.

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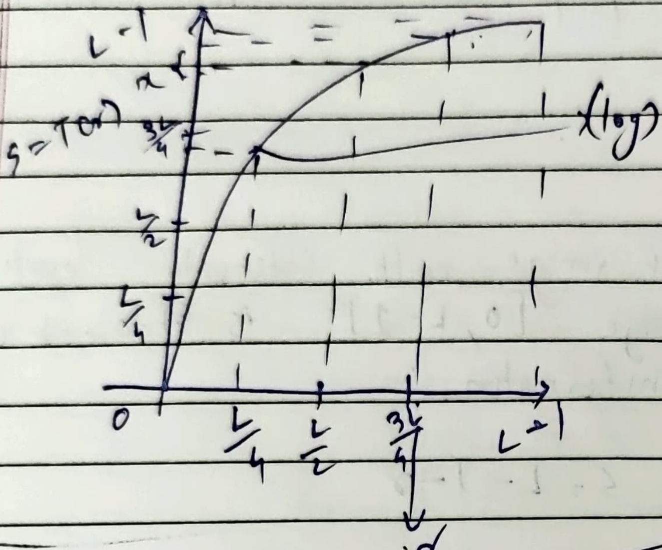
log transformation

$$s = c \log(1+r) \qquad r \geq 0$$



mapping ('narrow range of low intensity values in the input into wider range of output levels)

(it compresses ~~wide range~~ ~~dynamic range~~ of pixel values)

Input → output

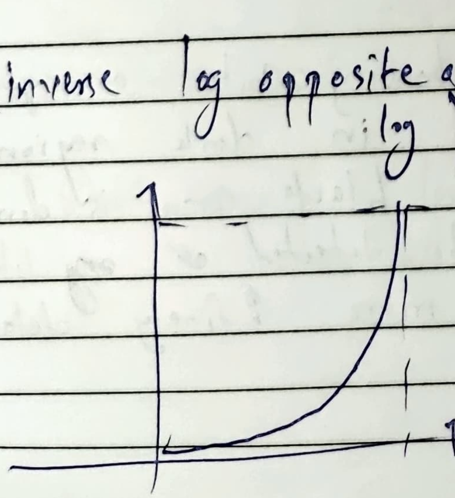
$\left[0, \frac{L}{4}\right] \longrightarrow \left[0, \frac{3L}{4}\right]$

input

$\left[\frac{L}{2}, \frac{3L}{4}\right] \longrightarrow x \rightarrow$ (range is very small)).

mapping wider ~~higher~~ range of high intensity values in input into narrow range of output levels

(inverse log opposite of log)



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power-law (gamma) transformations

$$s = c r^{\gamma}$$

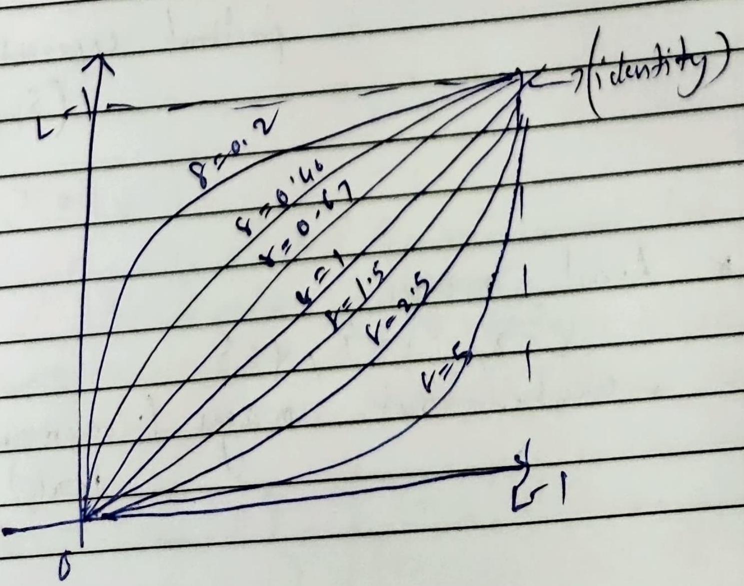
$$s = c(r + \epsilon)^{\gamma}$$
(offset)

* offsets typically are an issue of display calibration, and are ignored.

* family of transformation can be obtained by varying γ.

* $\gamma > 1$ curves have opposite effect as those are generated with $\gamma < 1$.

* $c = \gamma = 1$ → identity transformation
* The response of many devices used for image capturing obey a power law
* The process used to correct these power-law ~~resou~~ response phenomena is called gamma correction or gamma encoding



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Example
Cathode ray tube (CRT) devices have an intensity-to-voltage response that is a power function, with exponents varying from approximately 1.8 to 2.5

- Image is viewed on monitor with $\gamma = 2.5$

- So before showing the image on monitor we apply gamma transformation with $\gamma = 0.4$ on original image.
- Then when it is displayed a proper image is shown.

$$s = c\,r^{\frac{1}{2.5}} = c\,r^{0.4}$$

Use:

- MRI (magnetic resonance image) of a human upper spine with a fracture dislocation.
- The fracture is visible. (Here we use power law transformation with a fractional exponent $(s = c\,r^{\gamma})$

$(\gamma = 0.6, 0.4, 0.3)$

- Aerial images
$\gamma = 3, \gamma = 4, \gamma = 5$
- washed-out images (compression of intensity levels).

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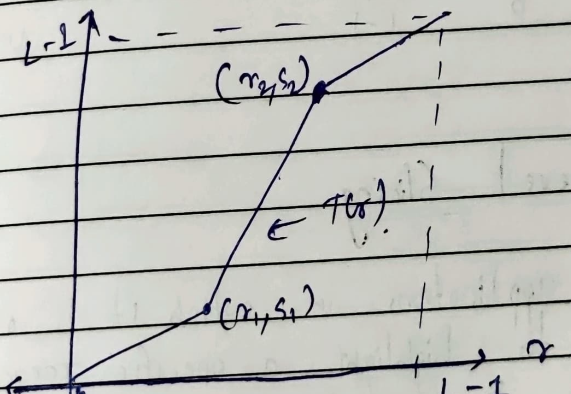
Piecewise linear transformation functions

~~Constr~~

Contrast streching

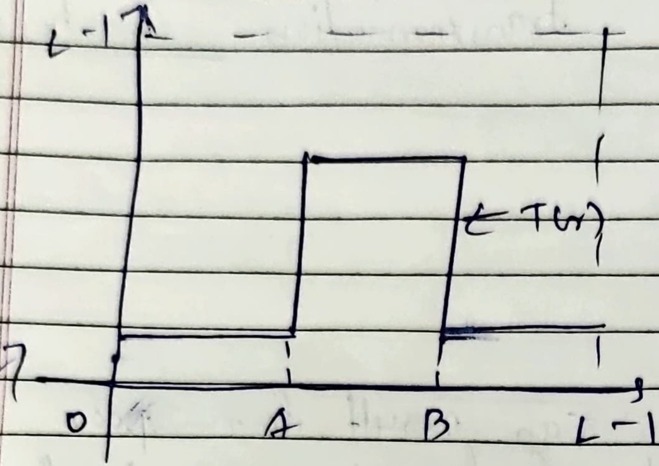
* Low-contrast images can result from poor illumination, lack of dynamic range in the imaging sensor
* Contrast streatching expands the range of intensity levels in an image so that it spans the ideal full intensity range of the recording medium or display device.



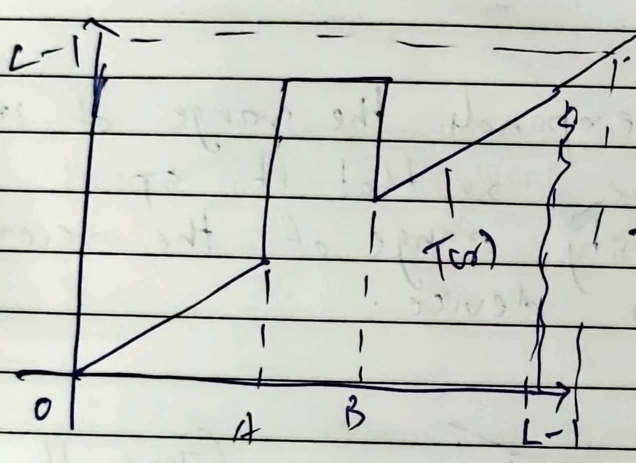
Generally ($r_1 \le r_2$ and $s_1 \le s_2$)

* location of (r_1, s_1) and (r_2, s_2) control the shape of transformation function.
* $r_1 = s_1$ and $r_2 = s_2$ → (No change in intenecity).
* $r_1 = r_2$, $s_1 = 0$, $s_2 = L-1$ (thresholding function).
* $(r_1, s_1) \to (r_{min}, 0)$
  $(r_2, s_2) \to (r_{max}, L-1)$

$(r_1, s_1) \to (m, 0)$
$(r_2, s_2) \to (m, L-1)$ (m = mean of intensity levels)



(this highlights range [A,B] and reduces all other intensities.



(this highlights range [A,B] and leaves other intensities unchanged).

Intensity-Level Slicing

* There are applications in which it is of interest to highlight a specific range of intensities in an image.
* enhancing features in satellite imagery, such as masses of water
* enhancing flows in X-ray images.

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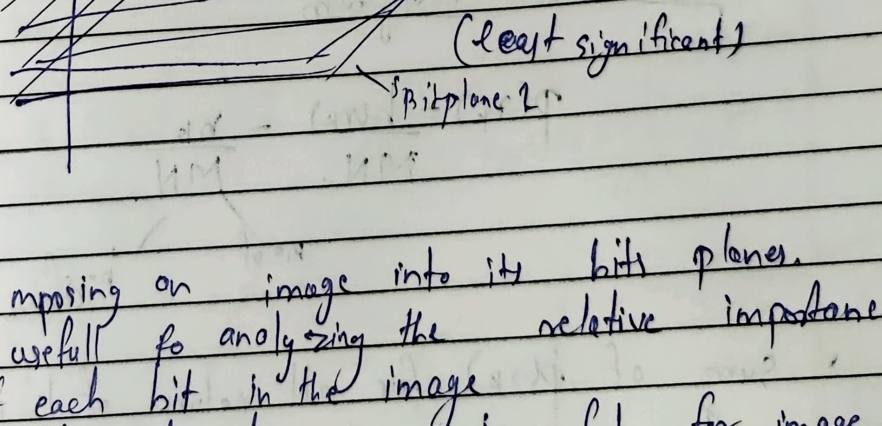
Bit plane Slicing

- Pixel values are integers composed of bits.
- Values in a 256-level gray-scale image are composed of 8 bits.

- Instead of highlighting intensity-level ranges, we could highlight the contribution made to total image appearance by specific bits.

- 8 bit image may be considered as being composed of eight one-bit planes with plane 1 containing the lowest-order bit of all pixels in the image, and plane 8 all the highest-order bits.



- Decomposing an image into its bits planes is usefull to analyzing the relative importance of each bit in the image
- This type of decomposing is useful for image compression
- In some images four high-order bit planes could allow you to construct the original image in acceptable detail. Storing these four planes requires

~~Ke~~ 50% less storage.

3.3 Histogram processing

let r_k, for $k = 0, 1, 2 \ldots L-1$. denote the intensities of an L-level digital image, $f(x,y)$

unnormalized histogram

$$h(r_k) = n_k \quad \text{for } k = 0, 1, 2, \ldots L-1$$

where n_k, is the number of pixels in f with intensity r_k

the subdivisions of the intensity scale are called histogram bins

normalized histogram

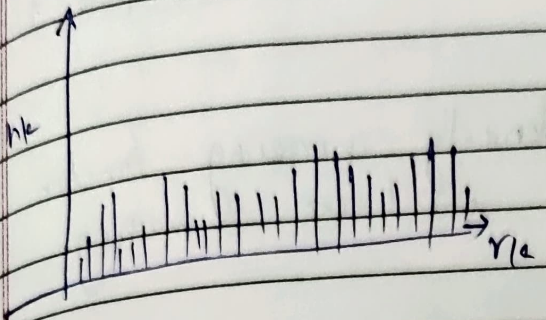
$$p(r_k) = \frac{h(r_k)}{MN} = \frac{n_k}{MN}$$

M: no. of rows
N: no. of columns

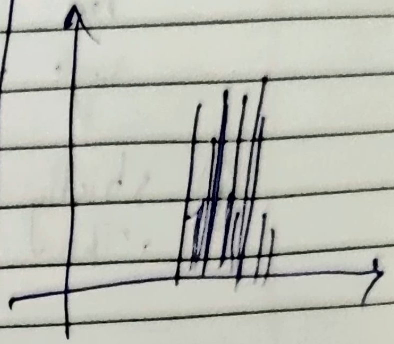
1) sum of $p(r_k)$ for all values of k is always 1.

2) The components of $p(r_k)$ are estimates of the probabilities of intensity levels occurring in an Image.

Histogram of highcontrast image



low contrast



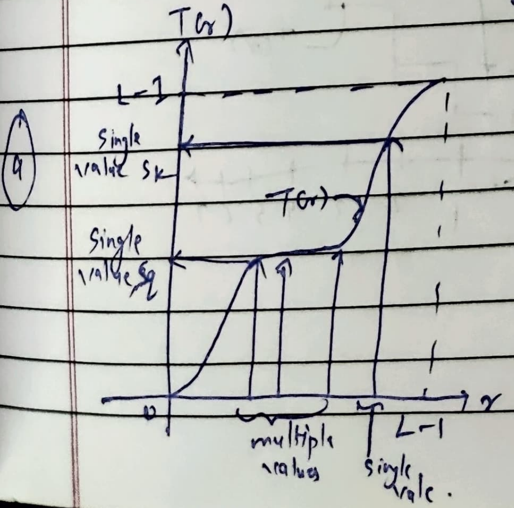
- the distribution of pixel is uniform, with few bins higher.
- Conclusion: Image whose pixels tend to be distributed uniformly will have appearance of high contrast and will exhibit a large variety of gray tones.

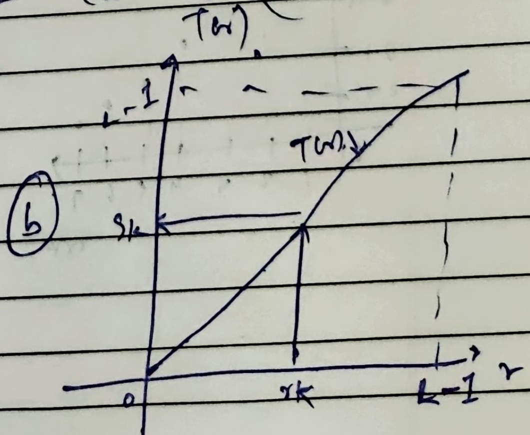
Histogram equalization

- Assume continuous intensity values
- r denote the intensities of image to be processed.

$r \in [0, L-1]$ $r=0$ black
$r = L-1$ (white).

$s = T(r)$
$0 \le r \le L-1$





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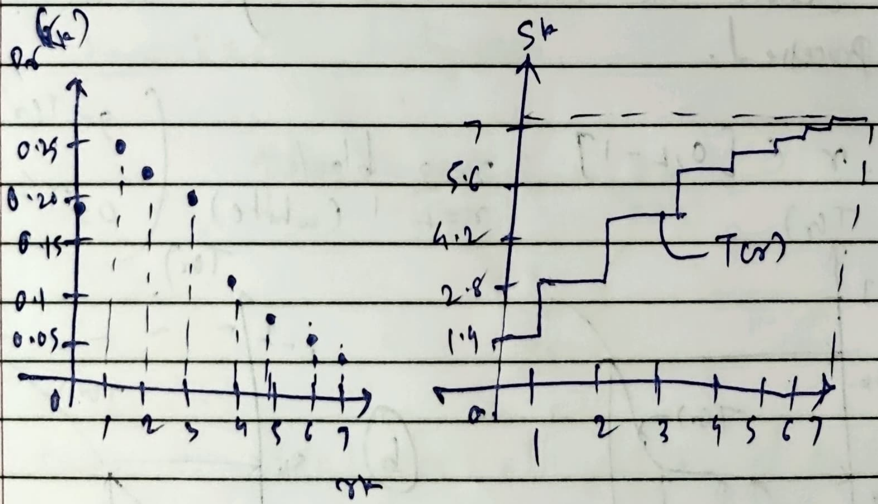
(a) ~~how~~ monotonically increasing function showing multiple values can map to a single value.

(b) strictly monotonically increasing function. This is a one-to-one mapping.

$MN \rightarrow$ total number of pixels in the image
$n_k \rightarrow$ number of pixels that have intensity ~~xxx~~ r_k

$r_k \in [0, L-1]$

$$\underbrace{s_k = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j) \quad (k = 0, 1, 2, \ldots L-1)}_{\text{(Histogram equalization or histogram linearization transformation)}}$$



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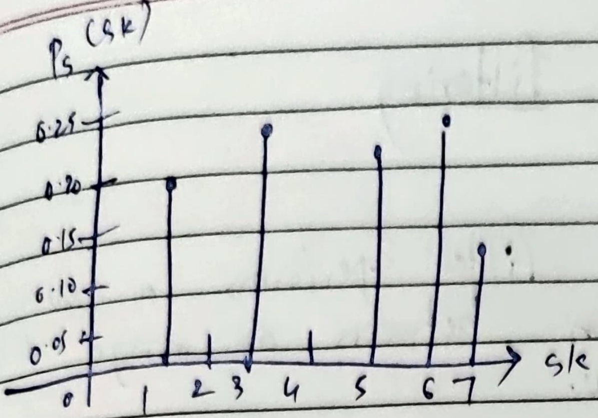

3.4 Fundamentals of spatial filtering.

- filtering refers to passing, modifying, or rejecting specified frequency components of an image.

Examples :- a filter that passes low frequencies is called a lowpass filter.

+ net effect produced by a lowpass filter is to smooth an image by blurring it.

- Spatial filtering modifies an image by replacing the value of each pixel by a ~~fun~~ function of the values of the pixel and its neighbors.

  - → linear spatial filter
  - → nonlinear spatial filter

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Linear spatial filtering

A linear spatial filter performs a sum-of-products operation between an image f and a filter kernel, w.

kernel → It is an array whose size defines the neighborhood of operation, & whose coefficients determine the nature of the filter.

(mask, template and window)

3×3 kernel:
at a point (x,y) in the image

$$g(x,y) = w(-1,-1)f(x-1,y-1) + w(-1,0)f(x-1,y) + \ldots + w(0,0)f(x,y) + \ldots + w(1,1)f(x+1,y+1)$$

Center coefficient of the kernel: $w(0,0)$

kernel size $m \times n$

$m = 2a+1$
$n = 2b+1$
(where a, b are non-negative integers)

$$g(x,y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t) f(x+s, y+t)$$

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Correlation and Convolution

- Correlation consists of moving the center of a kernel over an image, and computing the sum of products at each location.

- Spatial Convolution are the same, except that the correlation kernel is rotated by 180°.

- when the values of a kernel are symmetric about its center, correlation and convolution yield the same result.

If $a = 0$ $\quad m = 1$ $\quad$ kerner
$b = 2$ $\quad n = 5$

$$g(x) = \sum_{s=-b}^{b} w(s)\, f(x+s)$$

$m \times n = 1 \times 5$

kernel $[1\ 2\ 4\ 2\ 8]$

(Correlation)
(Sum of product)
Apply on every pixel.

zero padding

Image $\overbrace{0\ 0}\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 0$
$[1\ 2\ 4\ 2\ 8]$

we get final Image $(0\ 8\ 2\ 4\ 2\ 1\ 0\ 0)$

Convolution

we get final image $[0\ 1\ 2\ 4\ 2\ 8\ 0\ 0]$

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3.5 Smoothing (Lowpass) spatial filters

* Smoothing (also called averaging) spatial filters are used to reduce ~~sh~~ sharp transitions in intensity.

* Random noise consists of sharp transitions in intensity, an obvious application of smoothing is noise reduction.

* It is used to reduce "irrelevant" refers to pixel regions that are small with respect to the size of the filter kernel.

* Convolving a smoothing kernel with an image blurs the image, with the degree of blurring being determined by the size of the kernel and values of its coefficients.

Box Filter kernels

* Simplest separable lowpass filter kernel is the ~~box~~ box kernel whose coefficient have same value (typically 1).

* An mxn box filter is an mxn array of 1's with a normalizing constant in front.

$$\text{constant} = \frac{1}{(\text{sum of values of the coefficients})}$$

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* The normalization has two purposes :-
  * The avg value of an area of constant intensity would equal that intensity in the filtered image
  * It introduces bias during filtering, that is the sum of the pixels of the original and filtered images will be same.

Lowpass gaussian filter kernels

$$w(s,t) = G(s,t) = K e^{-\left(\frac{s^2+t^2}{2\sigma^2}\right)}$$

* circularly symmetric kernels
* $r = (s^2+t^2)^{\frac{1}{2}}$

$$G(r) = K e^{\frac{-r^2}{2\sigma^2}}$$