IMAGE PROCESSING

HISTOGRAM OF AN IMAGE

A histogram is a graph that shows frequency of anything..

image histogram shows frequency of pixels intensity values.

the x axis shows the gray level intensities and the y axis shows the frequency of these intensities.

- Lược đồ ảnh là phân bố các giá trị mức xám (màu) của một ảnh
- H(k) = tổng số pixel trong ảnh có giá trị k

APPLICATIONS OF HISTOGRAMS

We can predict about an image by just looking at its histogram. Its like looking an x ray of a bone of a body.

The second use of histogram is for brightness purposes And adjusting contrast of an image.

Another important use of histogram is to equalize an image.

And last but not the least, histogram has wide use in thresholding. This is mostly used in computer vision.

Image dynamic range = [min_value, max_value]

LUMINANCE - BRIGHTNESS (ĐỘ SÁNG)

- Luminance indicates how much luminous power can be perceived by the human eye, luminance indicates the brightness of light emitted or reflected off of a surface
- của một ảnh được định nghĩa là giá trị trung bình của tất cả các mức xám trong ảnh

- Illuminance is a term that describes the measurement of the amount of light falling onto (illuminating) and spreading ove a given surface area

CONTRAST (ĐỘ TƯƠNG PHẢN)

Contrast can be simply explained as the difference between maximum and minimum pixel intensity in an image.

- Standard deviation of the gray levels

$$C = \sqrt{\frac{1}{M \times N} \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} (f(x,y) - Moy)^2}$$

- Variation between the min and max gray level

$$C = \frac{\max[f(x,y)] - \min[f(x,y)]}{\max[f(x,y)] + \min[f(x,y)]}$$

CONTRAST (ĐỘ TƯƠNG PHẢN)

Hai ảnh dưới đây khác nhau về độ tương phản

EXAMPLE LUMINANCE AND CONTRAS IMAGES

a b

FIGURE 3.15 Four basic image types: dark, light, low contrast, high contrast, and their corresponding histograms. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra, Australia.)

Source : Gonzalez and Woods. Digital Image Processing. Prentice-Hall, 2002.

IMAGE ENHANCEMENT

Chuyển đổi tuyến tính
Piecewise linear transform
Non-linear transform
Histogram equalization

Source : Caroline Rougier. Traitement d'images (IFT2730). Univ. de Montréal.

IMAGE ENHANCEMENT

Enhancing an image provides better contrast and a more detailed image as compare to non enhanced image.

It is used to enhance medical images, images captured in remote sensing, images from satellite e.t.c

GRAY LEVEL TRANSFORMATION

The transformation function has been given below

s = T (r)

where r is the pixels of the input image and s is the pixels of the output image.

T is a transformation function that maps each value of r to each value of s.

Image enhancement can be done through gray level transformations

There are three basic gray level transformation.

- Linear
- Logarithmic
- Power – law

GRAY LEVEL TRANSFORMATION

Negative transformation

Power – Law transformations --→

Gama 10,8,6

Log Tranform Image

METHODS OF HISTOGRAM

There are two methods of enhancing contrast.

- The first one is called Histogram stretching that increase contrast.
- The second one is called Histogram equalization that enhance contrast

HISTOGRAM STRETCHING

Source : Caroline Rougier. Traitement d'images (IFT2730). Univ. de Montréal.

HISTOGRAM STRETCHING

The formula for stretching the histogram of the image to increase the contrast

Those cases include images with when there is pixel intensity 0 and 255 are present in the image

Note *: this method of increasing contrast does not work always*

$$I'(i,j) = \frac{255}{\max - \min}(I(i,j) - \min) \quad with \frac{(I(i,j) - \min)}{\max - \min} \in [0,1]$$

Source : Caroline Rougier. Traitement d'images (IFT2730). Univ. de Montréal.

HISTOGRAM EQUALIZATION

Histogram equalization is a technique for adjusting image intensities to enhance contrast.

Histogram equalization redistributes the pixel intensity values evenly by using cumulative(sum) histogram as a transfer function or as a look-up table.

HISTOGRAM EQUALIZATION

In histogram equalization, the input pixel intensity, x is transformed to new intensity value, x′ by T.

The transform function, T is the product of a cumulative histogram and a scale factor.

The scale factor is needed to fit the new intensity value within the range of the intensity values, for example, 0 ~ 255.

0
50
100
150
200
250

0
50
100
150
200
250

STEP 1 - PMF (PROBABILITY MASS FUNCTION)

The 8-bit grayscale image shown has the following values:

$$\begin{bmatrix} 52 & 55 & 61 & 66 & 70 & 61 & 64 & 73 \\ 63 & 59 & 55 & 90 & 109 & 85 & 69 & 72 \\ 62 & 59 & 68 & 113 & 144 & 104 & 66 & 73 \\ 63 & 58 & 71 & 122 & 154 & 106 & 70 & 69 \\ 67 & 61 & 68 & 104 & 126 & 88 & 68 & 70 \\ 79 & 65 & 60 & 70 & 77 & 68 & 58 & 75 \\ 85 & 71 & 64 & 59 & 55 & 61 & 65 & 83 \\ 87 & 79 & 69 & 68 & 65 & 76 & 78 & 94 \end{bmatrix}$$

Value	Count	Value	Count	Value	Count	Value	Count	Value	Count
52	1	64	2	72	1	85	2	113	1
55	3	65	3	73	2	87	1	122	1
58	2	66	2	75	1	88	1	126	1
59	3	67	1	76	1	90	1	144	1
60	1	68	5	77	1	94	1	154	1
61	4	69	3	78	1	104	2		
62	1	70	4	79	2	106	1		
63	2	71	2	83	1	109	1		

PMF:First we have to calculate the PMF (probability mass function) of all the pixels in this image.

STEP 2 CDF (CUMULATIVE DISTRIBUTIVE FUNCTION)

CDF stands for cumulative distributive function. It is a function that calculates the cumulative sum of all the values that are calculated by PMF. It basically sums the previous one.

h(v) = round(cdf(v)-cdf(min))x255/(8x8-1)

This cdf shows that the minimum value in the sub-image is 52 and the maximum value is 154. The cdf of 64 for value 154 coincides with the number of pixels in the image.

The cdf must be normalized to [0 255]

v, Pixel Intensity	cdf(v)	h(v), Equalized v
52	1	0
55	4	12
58	6	20
59	9	32
60	10	36
61	14	53
62	15	57
63	17	65
64	19	73
65	22	85
66	24	93
67	25	97

$$\begin{bmatrix} 0 & 12 & 53 & 93 & 146 & 53 & 73 & 166 \\ 65 & 32 & 12 & 215 & 235 & 202 & 130 & 158 \\ 57 & 32 & 117 & 239 & 251 & 227 & 93 & 166 \\ 65 & 20 & 154 & 243 & 255 & 231 & 146 & 130 \\ 97 & 53 & 117 & 227 & 247 & 210 & 117 & 146 \\ 190 & 85 & 36 & 146 & 178 & 117 & 20 & 170 \\ 202 & 154 & 73 & 32 & 12 & 53 & 85 & 194 \\ 206 & 190 & 130 & 117 & 85 & 174 & 182 & 219 \end{bmatrix}$$

tice that the minimum value (52) is now 0 and the maximum value (154) is now 255.

Original Equalized

v, Pixel Intensity	cdf(v)	h(v), Equalized v
52	1	0
55	4	12
58	6	20
59	9	32
60	10	36
61	14	53
62	15	57
63	17	65
64	19	73
65	22	85
66	24	93
67	25	97

HISTOGRAM EQUALIZATION

Source image

More contrasted image

Source : Tal Hassner. Computer Vision. Weizmann Institute of Science (Israel).

HISTOGRAM EQUALIZATION

Histogram equalization *can improve the image contrast where* ***histogram dynamic correction*** *is of no use*

HISTOGRAM EQUALIZATION

*If we take the **same image** with **different contrasts**, histogram equalization will give the **same results** for all images*

a b c

FIGURE 3.17 (a) Images from Fig. 3.15. (b) Results of histogram equalization. (c) Corresponding histograms.

Source : Gonzalez and Woods. Digital Image Processing. Prentice-Hall, 2002.

LOGICAL OPERATORS CAN BE APPLIED TO IMAGES(**AND, OR**)

a b c
d e f

FIGURE 3.27 (a) Original image. (b) AND image mask. (c) Result of the AND operation on images (a) and (b). (d) Original image. (e) OR image mask. (f) Result of operation OR on images (d) and (e).

Source : Gonzalez and Woods. Digital Image Processing. Prentice-Hall, 2002.

IMAGE ADDITION

- If f and g are two images, the pixelwise addition R is defined as:

$$R(x,y) = \mathrm{Min}(\ f(x,y)+g(x,y)\ ;\ 255\ )$$

- Image addition is used to
  - lower the noise in a serie of images
  - increase the luminance by adding the image to itself

Source : Eric Favier. L'analyse et le traitement des images. ENISE.

IMAGE SUBSTRACTION

- The pixelwise substraction of two images f and g is:

  $$S(x,y) = Max(f(x,y)-g(x,y); 0)$$

- Image substraction is used to
  - detect defaults
  - detect motion in images

Source : Eric Favier. L'analyse et le traitement des images. ENISE.

IMAGE MULTIPLICATION

- The multiplication S of an image f by a ratio (factor) is defined as:S(x,y) = Max(f(x,y)*ratio ; 255)
- Image multiplication can be used to increase the contrast or the luminosity

x1,5 =

x1,2 =

Source : Eric Favier. L'analyse et le traitement des images. ENISE.

MỘT SỐ PHÉP TOÁN TRÊN CÁC ẢNH

Source : www.nte.montaigne.u-bordeaux.fr/SuppCours/5314/Dai/TraitImage01-02.ppt

CONVOLUTION

Blurring
Sharpening
Edge detection

WHY CONVOLUTION

Convolution can achieve something, that the previous methods of manipulating images can't achieve (Transformation, Histogram)

Those include the blurring, sharpening, edge detection, noise reduction e.t.c

WHAT IS MASK?

Mask is also a signal. It can be represented by a two dimensional matrix.

The mask is usually of the order of 1x1, 3x3, 5x5, 7x7 .

A mask should always be in odd number, because other wise you cannot find the mid of the mask.

Why do we need to find the mid of the mask.

The answer lies below, in topic of, how to perform convolution?

1	2	3
4	5	6
7	8	9

Flipping the mask horizontally

3	2	1
6	5	4
9	8	7

Flipping the mask vertically

9	8	7
6	5	4
3	2	1

HOW TO PERFORM CONVOLUTION?

In order to perform convolution on an image, following steps should be taken.

- Flip the mask (horizontally and vertically) only once
- Slide the mask onto the image.
- Multiply the corresponding elements and then add them
- Repeat this procedure until all values of the image has been calculated.

Let's consider an image to be like this

2	4	6
8	10	12
14	16	18

First pixel = (5*2) + (4*4) + (2*8) + (1*10)
= 10 + 16 + 16 + 10
= 52
Place 52 in the original image at the first index and repeat this procedure for each pixel of the image.

BLURRING

in blurring, we simple reduce the edge content and makes the transition form one color to the other very smooth.

Types of filters

Blurring can be achieved by many ways. The common type of filters that are used to perform blurring are.

- Mean filter
- Weighted average filter
- Gaussian filter

MEAN FILTER

Mean filter is also known as Box filter and average filter. A mean filter has the following properties.

It must be odd ordered

The sum of all the elements should be 1

All the elements should be same

If we follow this rule, then for a mask of 3x3. We get the following result.

Ex: 3x3, 5x5, 7x7

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

WEIGHTED AVERAGE FILTER

In weighted average filter, we gave more weight to the center value. Due to which the contribution of center becomes more then the rest of the values. Due to weighted average filtering, we can actually control the blurring.

Properties of the weighted average filter are.

- It must be odd ordered
- The sum of all the elements should be 1
- The weight of center element should be more then all of the other elements

1	1	1
1	2	1
1	1	1

1	1	1
1	10	1
1	1	1

GAUSSIAN BLUR (BLURRING)

In general, for symmetry f(u,v) = f(u) f(v)

- You might want to have some fun with asymmetric filters

We will use a Gaussian blur

- Blur width sigma depends on kernel size n (3,5,7,11,13,19)

Spatial

Frequency

$$f(u) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left[\frac{-u^2}{2\sigma^2}\right] \qquad \sigma = floor(n/2)/2$$

Slide credit: Ravi Ramamoorthi

DISCRETE FILTERING, NORMALIZATION

Gaussian is infinite

- In practice, finite filter of size n (much less energy beyond 2 sigma or 3 sigma).
- Must renormalize so entries add up to 1

Simple practical approach

- Take smallest values as 1 to scale others, round to integers
- Normalize. E.g. for n = 3, sigma = ½

$$f(u,v) = \frac{1}{2\pi\sigma^2}\exp\left[-\frac{u^2+v^2}{2\sigma^2}\right] = \frac{2}{\pi}\exp\left[-2\left(u^2+v^2\right)\right]$$

$$\approx \begin{pmatrix} 0.012 & 0.09 & 0.012 \\ 0.09 & 0.64 & 0.09 \\ 0.012 & 0.09 & 0.012 \end{pmatrix} \approx \frac{1}{86}\begin{pmatrix} 1 & 7 & 1 \\ 7 & 54 & 7 \\ 1 & 7 & 1 \end{pmatrix}$$

Slide credit: Ravi Ramamoorthi

Slide credit: Ravi Ramamoorthi

WHY DETECT EDGES

Most of the shape information of an image is enclosed in edges.

So first we detect these edges in an image and by using these filters and then by enhancing those areas of image which contains edges, sharpness of the image will increase and image will become clearer.

EDGE DETECTION WHAT ARE EDGES

We can also say that sudden changes of discontinuities in an image are called as edges.

Significant transitions in an image are called as edges.

Generally edges are of three types:

- Horizontal edges
- Vertical Edges
- Diagonal Edges

Prewitt Operator

Sobel Operator

Robinson Compass Masks

Krisch Compass Masks

Laplacian Operator.

SHARPENING FILTER

Sharpening is opposite to the blurring. In blurring, we reduce the edge content and in Sharpening, we increase the edge content.

So in order to increase the edge content in an image, we have to find edges first.

$$f(x,y) = \frac{1}{7}\begin{pmatrix} -1 & -2 & -1 \\ -2 & 19 & -2 \\ -1 & -2 & -1 \end{pmatrix}$$

SHARPENING (LÀM SẮC NÉT)

Slide credit: Bill Freeman

SHARPENING

Slide credit: Bill Freeman

Các bộ lọc phi tuyến

Median filter

Bilateral filter

Cross-bilateral filter

LỌC TRUNG VỊ - MEDIAN FILTERING

Lọc Trung vị là một kĩ thuật lọc phi tuyến (non-linear), nó khá hiệu quả đối với hai loại nhiễu: nhiễu đốm (speckle noise) và nhiễu muối tiêu (salt-pepper noise).

Best for salt and pepper noise

Ý TƯỞNG CHÍNH CỦA THUẬT TOÁN LỌC TRUNG VỊ NHƯ SAU:

sử dụng một cửa sổ lọc (ma trận 3x3) quét qua lần lượt từng điểm ảnh của ảnh đầu vào input.

Tại vị trí mỗi điểm ảnh lấy giá trị của các điểm ảnh tương ứng trong vùng 3x3 của ảnh gốc "lấp" vào ma trận lọc.

Sau đó sắp xếp các điểm ảnh trong cửa sổ này theo thứ tự (tăng dần hoặc giảm dần tùy ý).

Cuối cùng, gán điểm ảnh nằm chính giữa (Trung vị) của dãy giá trị điểm ảnh đã được sắp xếp ở trên cho giá trị điểm ảnh đang xét của ảnh đầu ra output.

MEDIAN FILTER

Replace each pixel by the median over N pixels (5 pixels, for these examples). Generalizes to “rank order” filters.

Median([1 7 1 5 1]) = 1
Mean([1 7 1 5 1]) = 2.8

In:

5-pixel neighborhood

Out:

Spike noise is removed

In:

Out:

Monotonic edges remain unchanged

OPERATIONS ON IMAGE

Panorama
Image Blending
Image Warping
Image Morphing

MOSAICS: STITCHING IMAGES TOGETHER

Slide credit: F. Durand

HOW TO DO IT?

Basic Procedure

- Take a sequence of images from the same position
  - Rotate the camera about its optical center
- Compute transformation between second image and first
- Transform the second image to overlap with the first
- Blend the two together to create a mosaic
- If there are more images, repeat

…but wait, why should this work at all?

- What about the 3D geometry of the scene?
- Why aren't we using it?

Slide credit: F. Durand

BEST BLENDING EXAMPLES

Merve

Alex Rubinsteyn

MORPHING = OBJECT AVERAGING

The aim is to find "an average" between two objects

- Not an average of two <u>images of objects</u>…
- …but an image of the <u>average object</u>!
- How can we make a smooth transition in time?
  - Do a "weighted average" over time t

How do we know what the average object looks like?

- We haven't a clue!
- But we can often fake something reasonable
  - Usually required user/artist input

Slide credit: Alyosha Efros

IDEA #1: CROSS-DISSOLVE

Interpolate whole images:

$\text{Image}_{\text{halfway}} = (1\text{-}t)*\text{Image}_1 + t*\text{image}_2$

This is called **cross-dissolve** in film industry

But what is the images are not aligned?

Slide credit: Alyosha Efros

IDEA #3: LOCAL WARP, THEN CROSS-DISSOLVE

Morphing procedure:

for every t,

1. Find the average shape (the "mean dog"☺)
   - local warping
2. Find the average color
   - Cross-dissolve the warped images

Slide credit: Alyosha Efros

LOCAL (NON-PARAMETRIC) IMAGE WARPING

Need to specify a more detailed warp function

- Global warps were functions of a few (2,4,8) parameters
- Non-parametric warps u(x,y) and v(x,y) can be defined independently for every single location x,y!
- Once we know vector field u,v we can easily warp each pixel (use backward warping with interpolation)

Slide credit: Alyosha Efros

IMAGE WARPING – NON-PARAMETRIC

Move control points to specify a spline warp

Spline produces a smooth vector field

Slide credit: Alyosha Efros

WARP SPECIFICATION - DENSE

How can we specify the warp?

Specify corresponding *spline control points*

But we want to specify only a few points, not a grid

Slide credit: Alyosha Efros

WARP SPECIFICATION - SPARSE

How can we specify the warp?

Specify corresponding *points*

- *interpolate* to a complete warping function
- How do we do it?

How do we go from feature points to pixels?

TRIANGULAR MESH

1. Input correspondences at key feature points
2. Define a triangular mesh over the points
   - Same mesh in both images!
   - Now we have triangle-to-triangle correspondences
3. Warp each triangle separately from source to destination
   - How do we warp a triangle?
   - 3 points = affine warp!
   - Just like texture mapping

Slide credit: Alyosha Efros

IMAGE PROPCESSING TOOLS

COMPOSITING LAYERS

Compositing layers

MAGIC WAND SELECTION

- Areas may be selected by drawing with marquee and lasso tools or a Bézier pen, or selected on the basis of colour similarity or edges using a magic wand or magnetic lasso.

Magic wand selection

MAGIC LASSO SELECTION

Magnetic lasso selection and mask

- Any selection defines a mask – the area that is not selected. Masked areas of the image are protected from changes.
- A greyscale mask, which is partially transparent, is an alpha channel.
- An alpha channel can be associated with a layer as a layer mask, and used for effects such as knock-outs and vignettes

COMPOSITING WITH A LAYER MASK

Compositing with a layer mask

VIGNETTING AN IMAGE

In pixel point processing, each pixel's new value depends only on its old value.

Brightness, contrast and levels are relatively crude pixel point adjustments.

Constructing a vignette with an alpha channel

TĂNG CƯỜNG ĐỘ TƯƠNG PHẢN VÀ ĐỘ SÁNG

Brightness (top) and contrast (bottom) adjustments