

Procesamiento de Señales e Imágenes

Ingeniería Biomédica

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Procesamiento de imágenes

What is Digital Image Processing?

Definition

- Two-dimensional function, $f(x, y)$
- Where x and y are spatial coordinates.
- The amplitude of f at any pair of coordinates (x, y) is called the intensity.

The digital image

If the coordinates and the intensity are discrete quantities the image turns into a digital image.

What is Digital Image Processing?

💡 Definition

A digital image is composed by a finite number of elements called PIXEL.

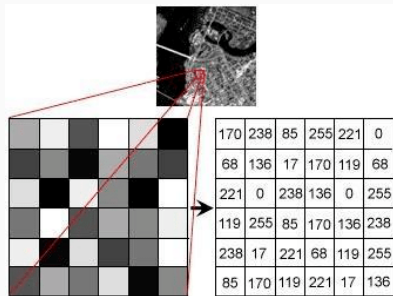


Figura 1:

<https://www.researchgate.net/figure/Digital-image-representation-by-pixels>

💡 Depth

A digital image is composed by a finite number of elements called PIXEL.

Bpp(Bits per pixel)

- 1bpp. B/W image, monochrome.
- 2bpp. CGA Image.

What is Digital Image Processing?

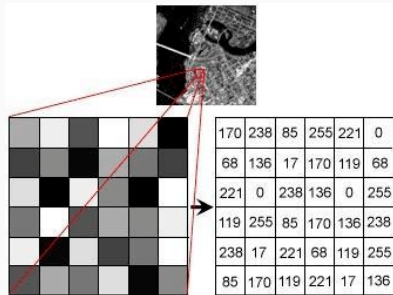


Figura 2:

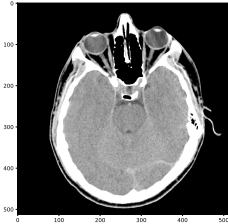
https://www.researchgate.net/figure/Digital-image-representation-by-pixels-vii_fig2_311806469

💡 Color Space

How can i represent the color

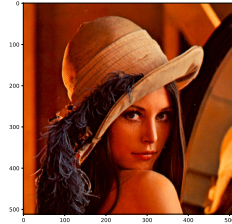
- RGB.
- CMYK.
- HSV.
- Among others.

What is Digital Image Processing?



```
import cv2
import matplotlib.pyplot as plt

img = cv2.imread(image_path+"img001.png")
fig001 = plt.figure()
plt.imshow(img)
```



```
import cv2
import matplotlib.pyplot as plt

img = cv2.imread(image_path+"img002.png")
RGB_img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
fig002 = plt.figure()
plt.imshow(RGB_img)
```

Images and vision

- The paradigm surrounding the conceptualization of light and perception has undergone significant evolution.
- Initially, the prevailing understanding within humanity posited that visual stimuli emanated from the eye itself.
- However, contemporary knowledge has elucidated that light originates from external sources, undergoes reflection from objects within the environment, and is subsequently captured by the eye.

Images and vision

i Important

We also understand that light is a type of electromagnetic radiation, and its wavelength falls within a range from 400 nanometers to 700 nanometers.

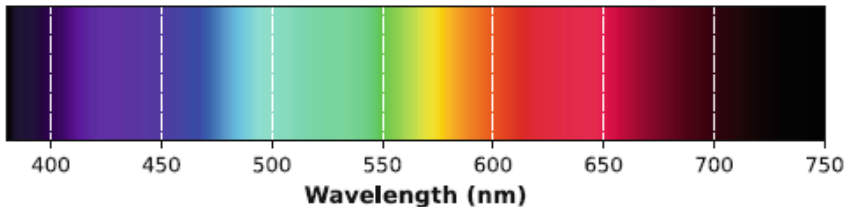


Figura 3: Taken from Corke 2023

i Important

- The most common way light is made is by something getting really hot. This makes energy that comes out as light.
- Some important term are:
 - *Absortion*: It is the fraction of light which a body absorbs depending on the wavelength.
 - *Reflectance*: It is the fraction of the incoming light which a body reflects. It's a number between 0 to 1 and also depends on wavelength.
 - *Luminance*: It is the fraction of the incoming light which a surface reflects. It's a function of absortion and reflectance, and because of that luminance depends on wavelength.

The eye

- Our eye has two types of cells. *Cones* and *Rods*.
- Cones are the most sensitive cells but above all these are color sensitive.
- Rods responds only two intensity and they used on night, mostly.
- Humans, like most primates, are trichomats. This means that humans have three types of cones (Long, Medium and shorts).
 - 65 % of longs (Sense red)
 - 33 % of mediums (Sense green)
 - 2 % of shortsv(Sense blue)

💡 The artificial eye

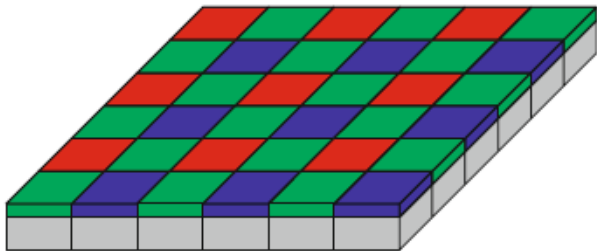
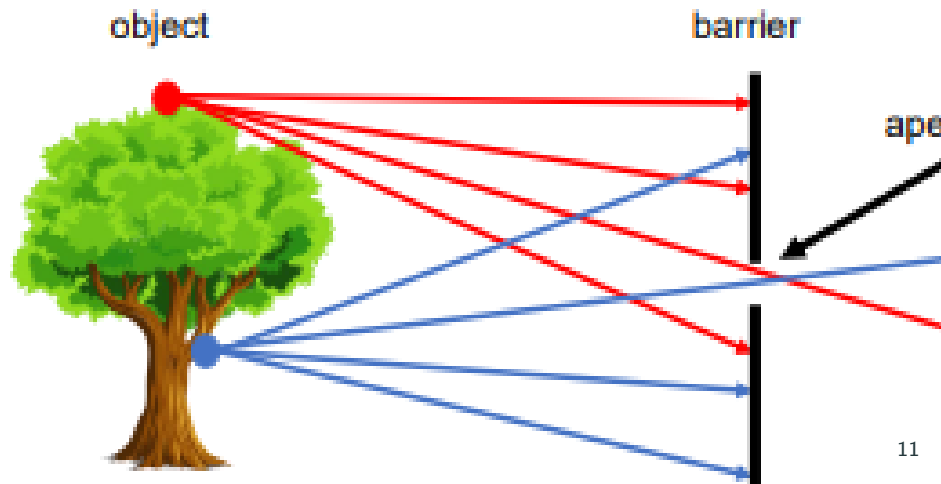
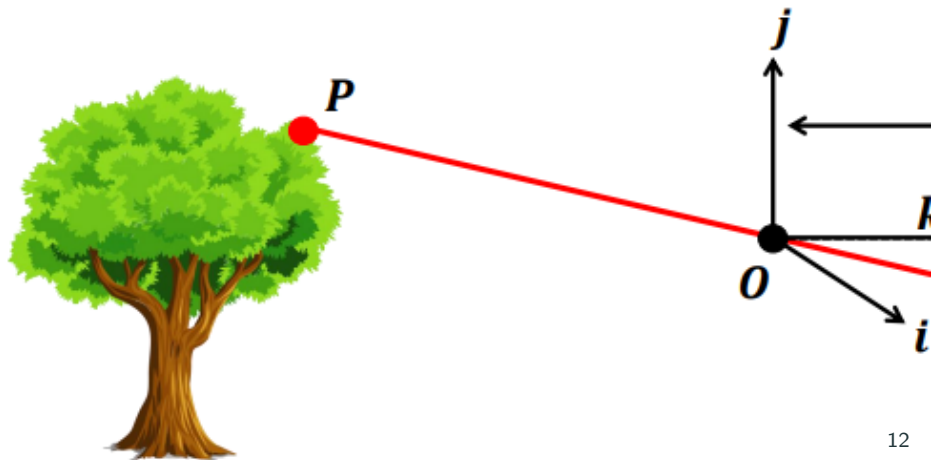


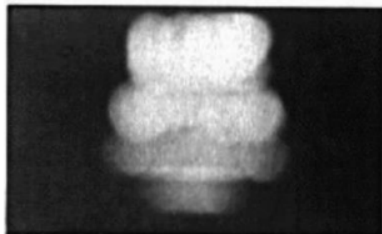
Figura 4: Taken from Corke 2023

The currents from each sensor are function of the luminance and the spectral response filter





Images and vision



2 mm



1 mm

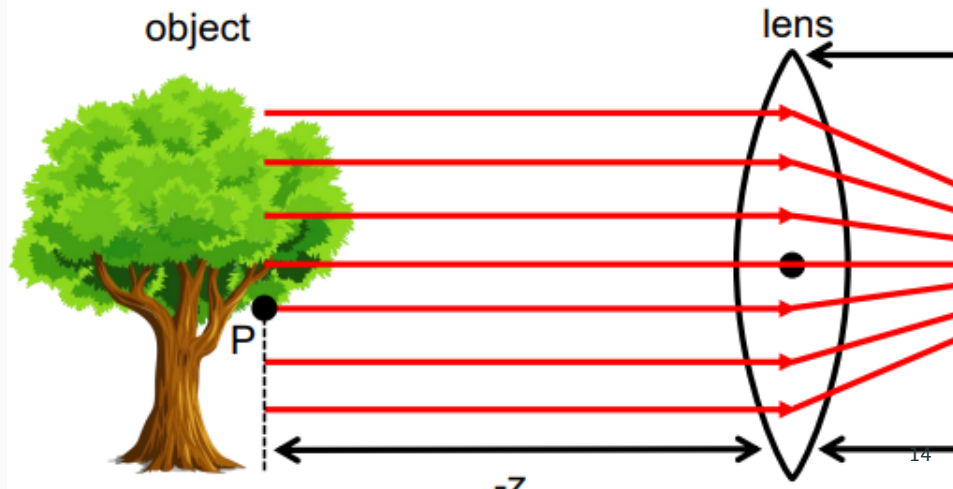


0.6 mm

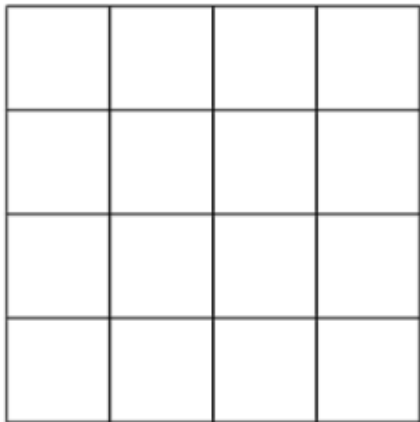


0.35 mm

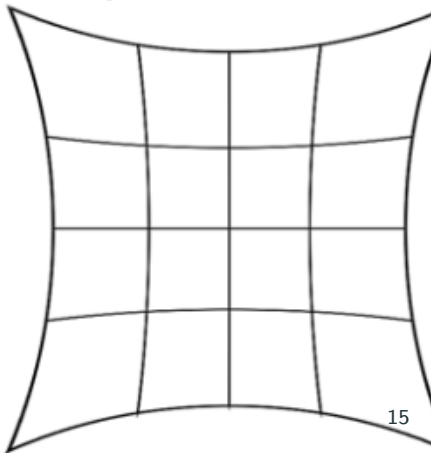
Images and vision



normal



pincushion



Sampling and quantization



Definition

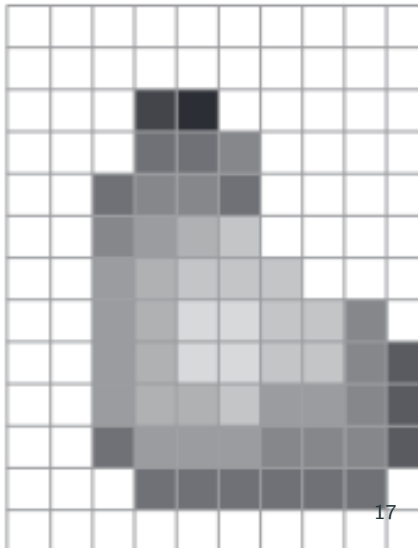
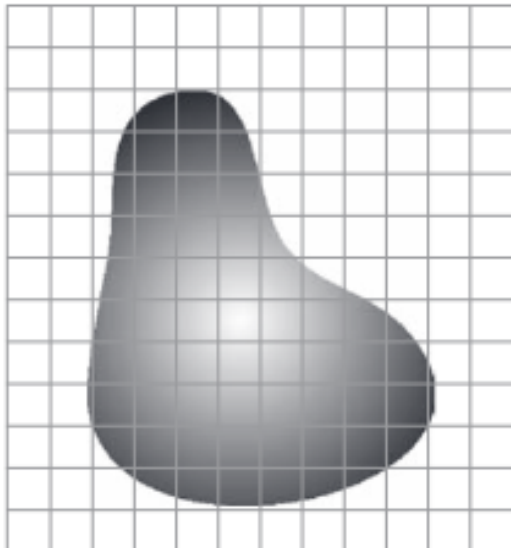
Sampling: Digitalization of the spatial coordinates.



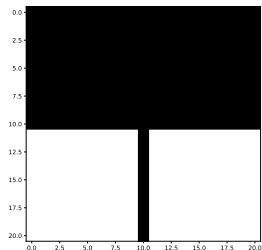
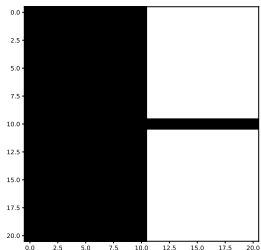
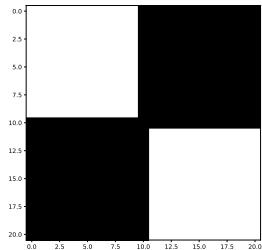
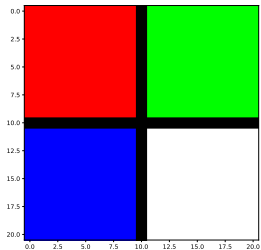
Definition

Quantiazation: Digitalization of the light intensity (amplitude).

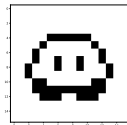
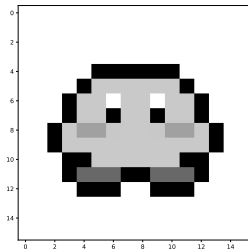
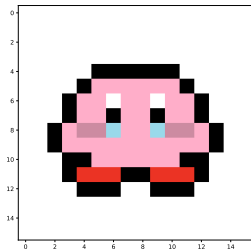
Sampling and quantization



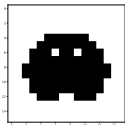
Sampling and quantization



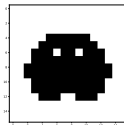
Sampling and quantization



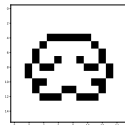
(a) 1bit



(a) 2bit

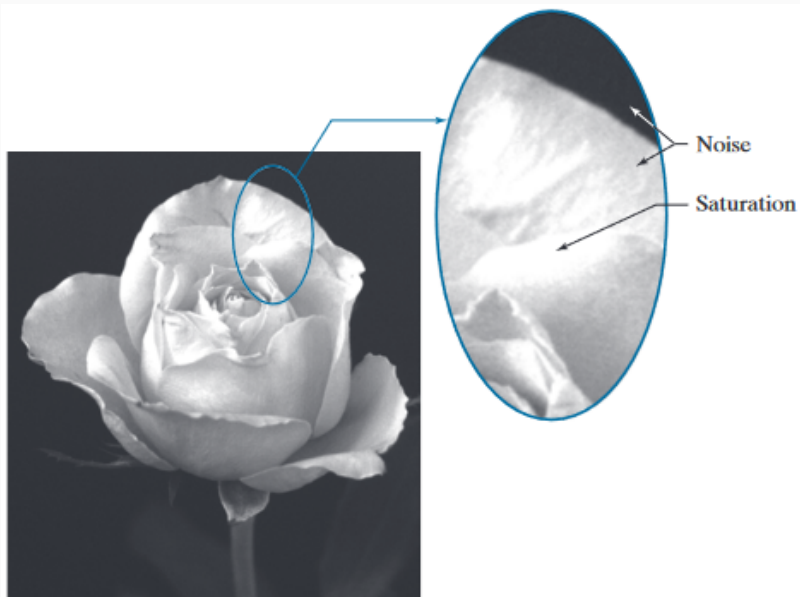


(a) 3bit

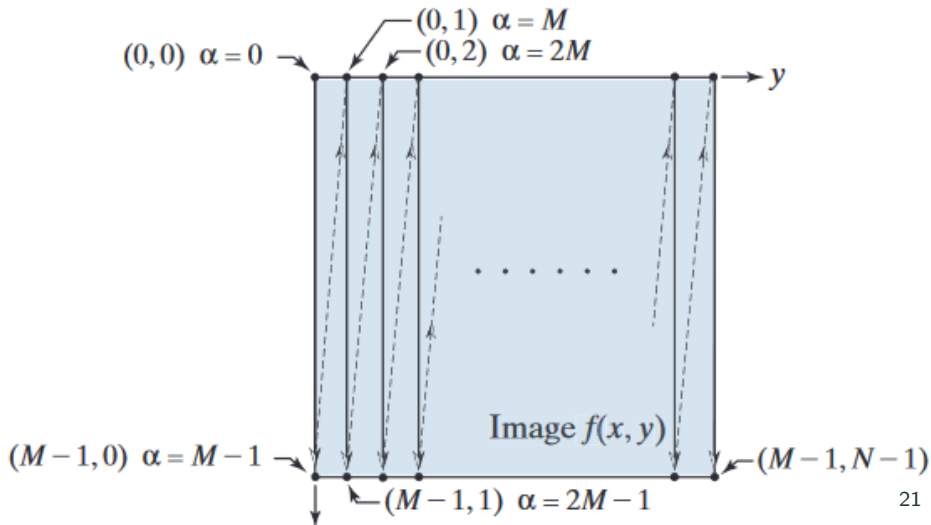


(a) 4bit

Sampling and quantization



Linear indexing



Spatial resolution

a b
c d

FIGURE 2.23
Effects of
reducing spatial
resolution. The
images shown
are at:
(a) 930 dpi,
(b) 300 dpi,
(c) 150 dpi, and
(d) 72 dpi.

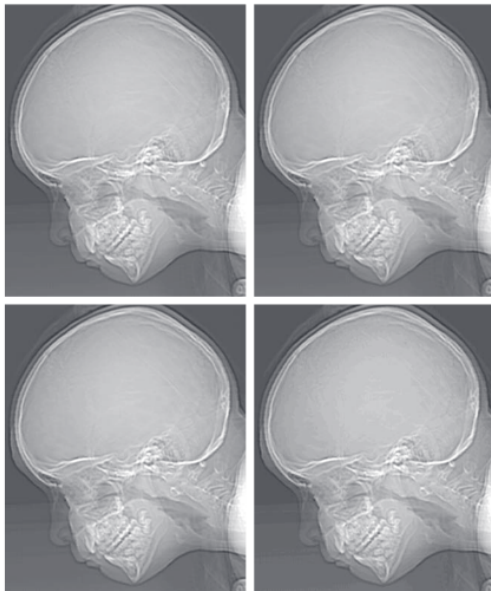


Intensity resolution

a b
c d

FIGURE 2.24

(a) 774×640 , 256-level image.
(b)-(d) Image displayed in 128, 64, and 32 intensity levels, while keeping the spatial resolution constant.
(Original image courtesy of the Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)



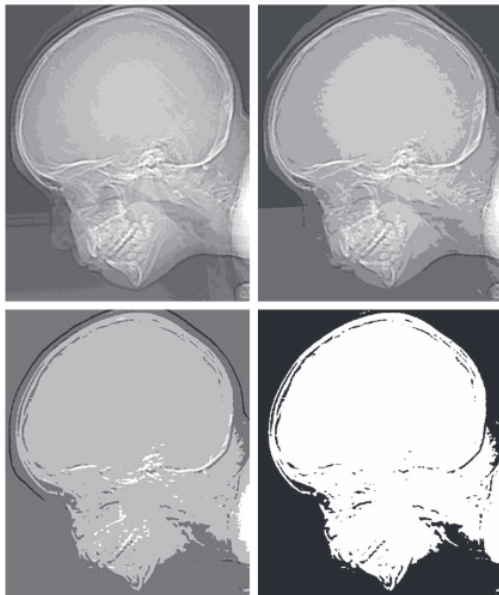
Intensity resolution

c f
g h

FIGURE 2.24

(Continued)

(e)-(h) Image displayed in 16, 8, 4, and 2 intensity levels.



“A simple problem”



Image

“A simple problem”



Semantic Segmentation

Relationships between pixels



Neighborhood

$(x-1, y-1)$	$(x, y-1)$	$(x+1, y-1)$	(x, y)	$(x-1, y+1)$	$(x, y+1)$	$(x+1, y+1)$
$(x-1, y)$	(x, y)	$(x+1, y)$	(x, y)	$(x-1, y)$	(x, y)	$(x+1, y)$
$(x-1, y+1)$	$(x, y+1)$	$(x+1, y+1)$	$(x, y+1)$	$(x-1, y+1)$	$(x, y+1)$	$(x+1, y+1)$

Relationships between pixels – Neighborhood



Neighborhood

$(x-1, y-1)$	$(x, y-1)$	$(x+1, y-1)$	(x, y)	$(x+1, y)$	$(x+2, y)$	$(x+3, y)$
$(x-1, y)$	(x, y)	$(x+1, y)$	$(x, y+1)$	$(x+1, y+1)$	$(x+2, y+1)$	$(x+3, y+1)$
$(x-1, y+1)$	$(x, y+1)$	$(x+1, y+1)$	$(x, y+2)$	$(x+1, y+2)$	$(x+2, y+2)$	$(x+3, y+2)$

Relationships between pixels – Adjacency

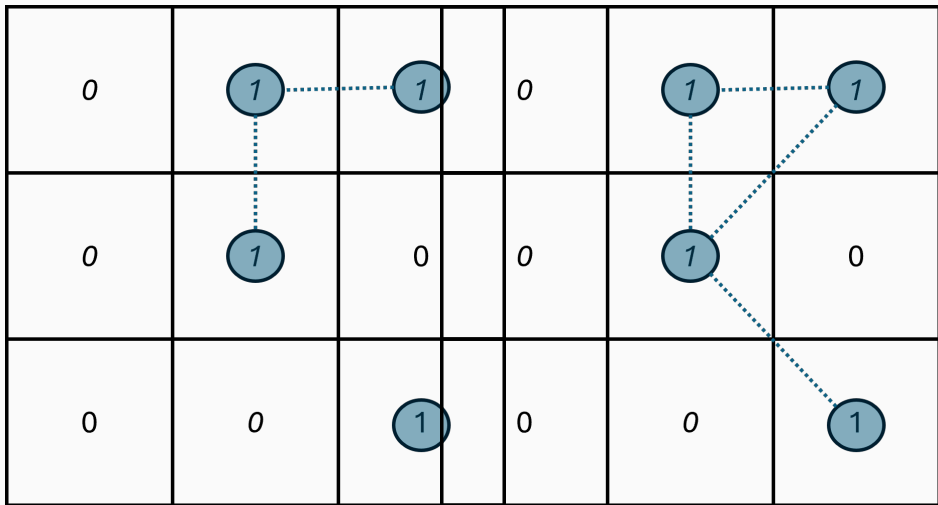
💡 Rules for adjacency

- 4-Adjacency: Two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$
- 8-adjacency. Two pixels p and q with values from V are 8-adjacent if q is in the set $N_8(p)$
- m-adjacency (also called mixed adjacency). Two pixels p and q with values from V are m-adjacent if:
 - q is in $N_4(p)$.
 - q is in $N_D(p)$ and the set $N_4(p) \cap N_4(q)$ has no pixels whose values are from V .

Relationships between pixels

0	1	1
0	1	0
0	0	1

Relationships between pixels



(a) A4

(a) A8

Relationships between pixels – Path

Digital path

It is a sequence of adjacent pixels.

$$(x_0, y_0), (x_1, y_1), (x_2, y_2), \dots (x_n, y_n)$$

If $(x_0, y_0) = (x_n, y_n)$ the path is known as closed path

Let S represent a subset of pixels in an image. Two pixels p and q are said to be connected in S if there exists a path between them consisting entirely of pixels in S .

Relationships between pixels – Path, Connected Subset

1	1	1	1	1
1	0	0	0	1
0	1	1	1	0
0	0	0	0	1
0	0	0	0	1
1	1	1	1	1
1	1	1	1	1

Relationships between pixels – Regions

1	1	1	1	1
1	0	0	0	1
0	1	1	1	0
0	0	0	0	1
0	0	0	0	1
1	1	1	1	1
1	1	1	1	1

Relationships between pixels – Boundary

0	0	0	0	0	0	0
0	1	1	1	0	0	0
0	1	1	1	0	0	0
0	1	1	1	0	0	0
0	1	1	1	0	0	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	1	1	1	1	1	0
0	0	0	0	0	0	0

Relationships between pixels – Distance



Distance

4	3	2	3
3	2	1	2
2	1	0	1
3	2	1	2

- City block distance:

$$D_1(p, q) = |x - u| + |y - v|$$

- Chessboard distance:

$$D_\infty(p, q) = \max(|x - u|, |y - v|)$$

- Euclidean distance:

$$D_2(p, q) = \sqrt{(x - u)^2 + (y - v)^2}$$

Relationships between pixels



Distance

2

2

2

2

2

1

1

1

2

1

0

1

2

1

1

1

- City block distance:

$$D_4(p, q) = |x - u| + |y - v|$$

- Chessboard distance:

$$D_8(p, q) = \max(|x - u|, |y - v|)$$

- Euclidean distance:

$$D_2(p, q) = \sqrt{(x - u)^2 + (y - v)^2}$$