

# Procesamiento de Señales e Imágenes

Ingeniería Biomédica

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# Procesamiento de imágenes

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# 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.

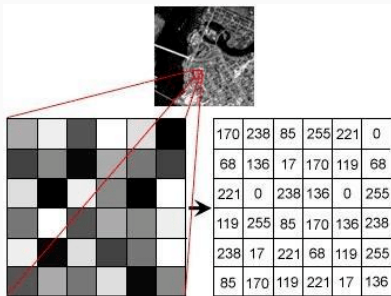
## The digital image

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>

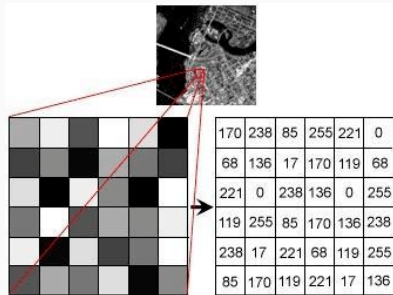
## 💡 Depth

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:**

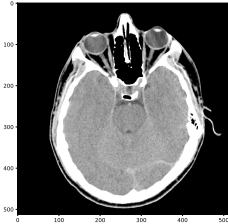
[https://www.researchgate.net/figure/Digital-image-representation-by-pixels-vii\\_fig2\\_311806469](https://www.researchgate.net/figure/Digital-image-representation-by-pixels-vii_fig2_311806469)

## 💡 Color Space

How can i represent the color

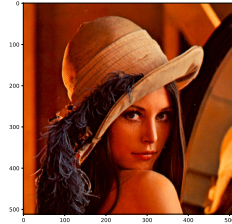
- RGB.
- CMYK.
- HSV.
- Among others.

# What is Digital Image Processing?



```
import cv2
import matplotlib.pyplot as plt

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



```
import cv2
import matplotlib.pyplot as plt

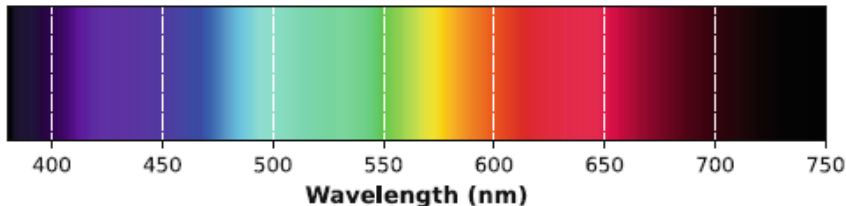
img = cv2.imread(image_path+"le
RGB_img = cv2.cvtColor(img, cv2
fig002 = plt.figure()
plt.imshow(RGB_img)
```

# 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.

## **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



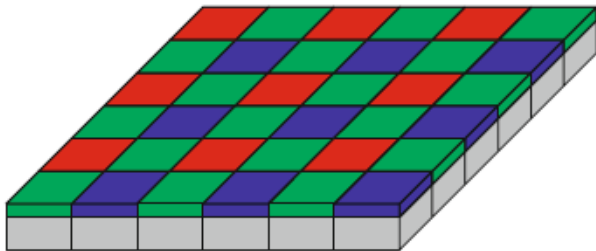
## **i** Important

- 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 absorption and reflectance, and because of that luminance depends on wavelength.

## The eye

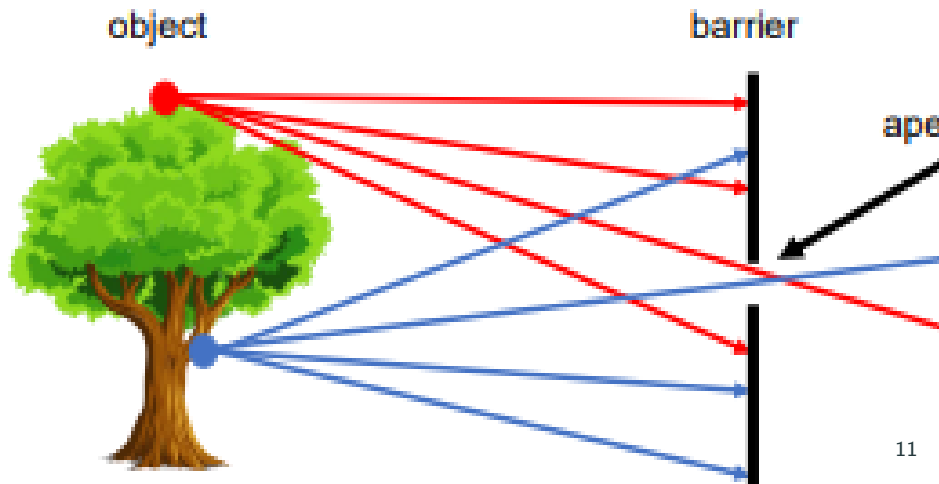
- Our eye has two types of cells. *Cones* and *Rods*.
- Cones are the most sensitive cells but above all these are color sensitive.
- Rods responds only two intensity and they used on night, mostly.
- Humans, like most primates, are trichomats. This means that humans have three types of cones (Long,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

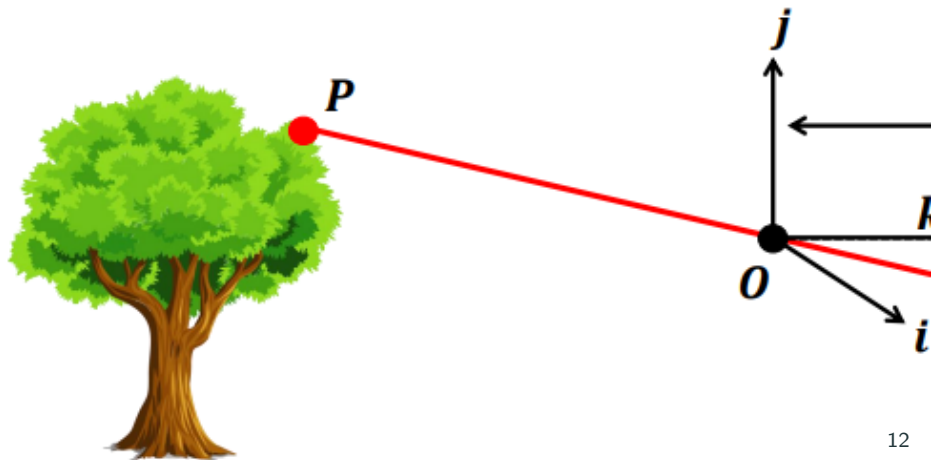
## 💡 The artificial eye



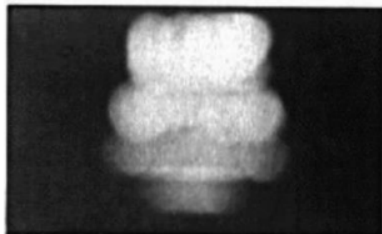
**Figura 4:** Taken from Corke 2023

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





## Images and vision



2 mm



1 mm

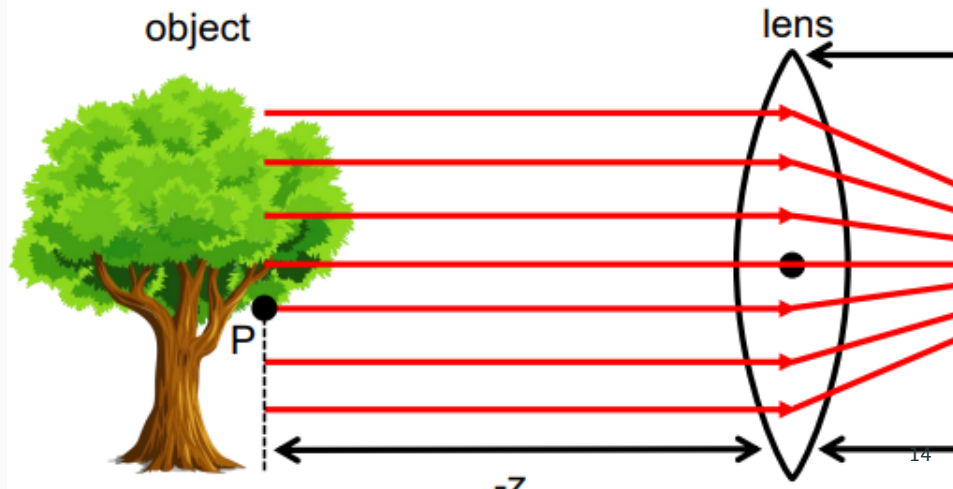


0.6 mm

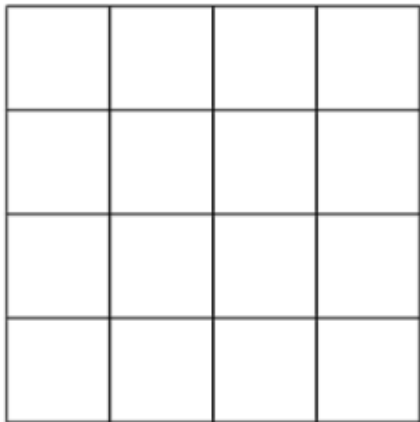


0.35 mm

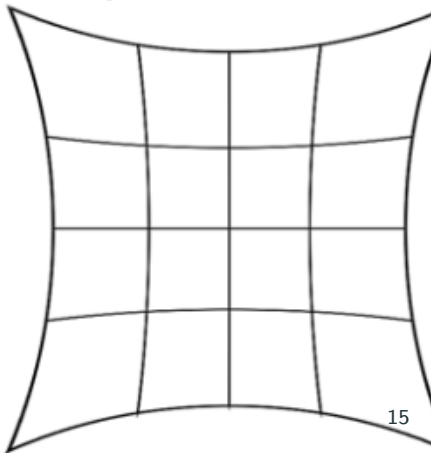
## Images and vision



normal



pincushion





# Sampling and quantization



## Definition

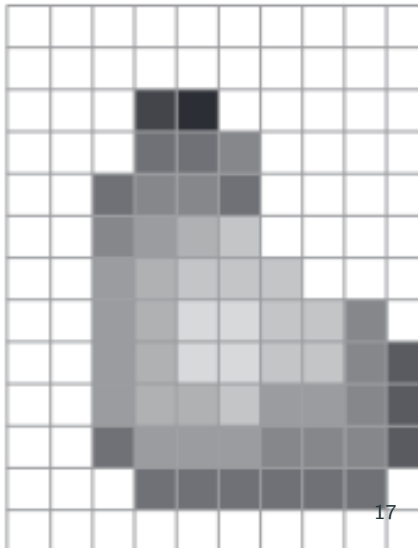
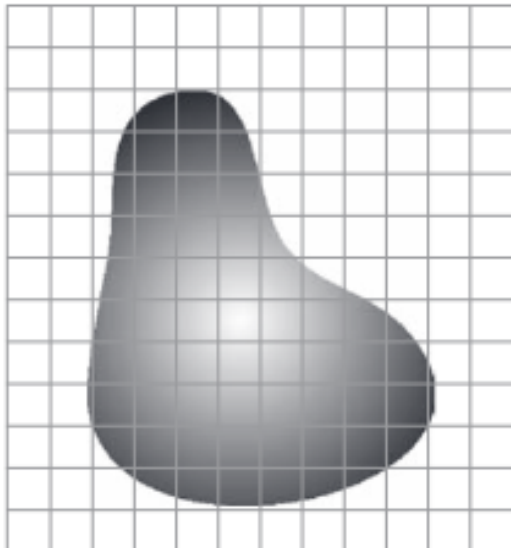
**Sampling:** Digitalization of the spatial coordinates.



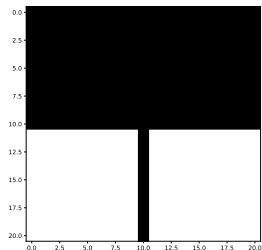
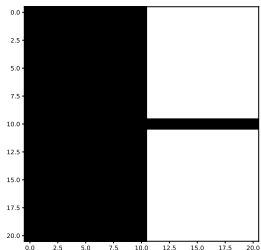
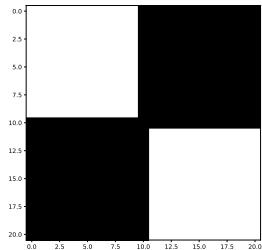
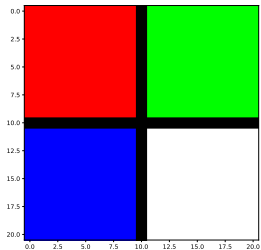
## Definition

**Quantization:** Digitalization of the light intensity (amplitude).

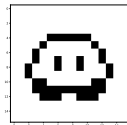
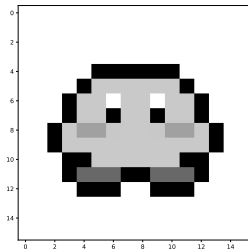
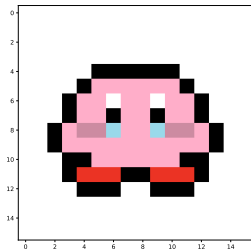
## Sampling and quantization



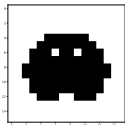
# Sampling and quantization



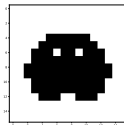
# Sampling and quantization



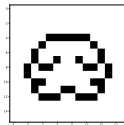
(a) 1bit



(a) 2bit

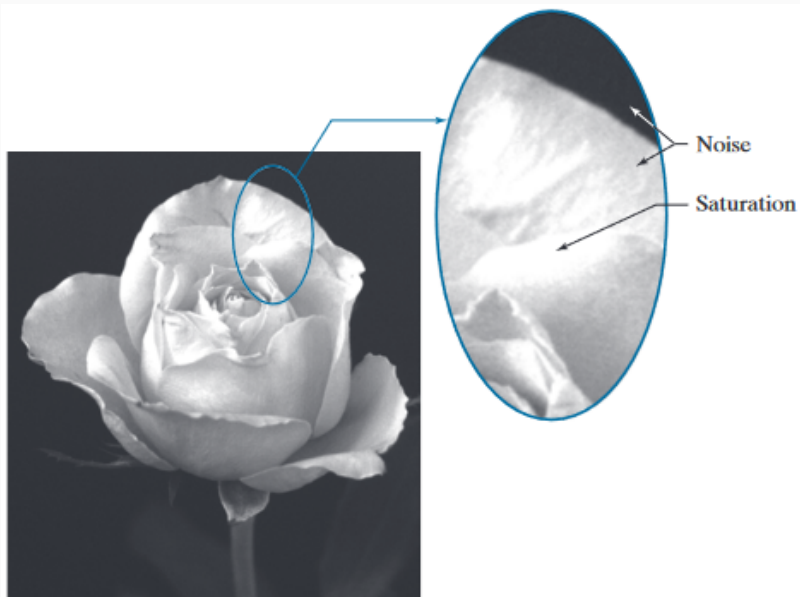


(a) 3bit

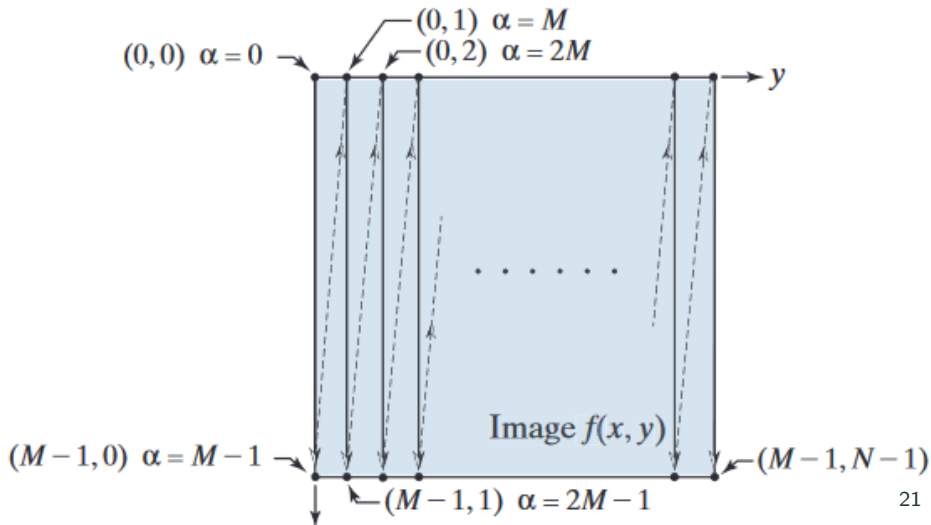


(a) 4bit

## 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.

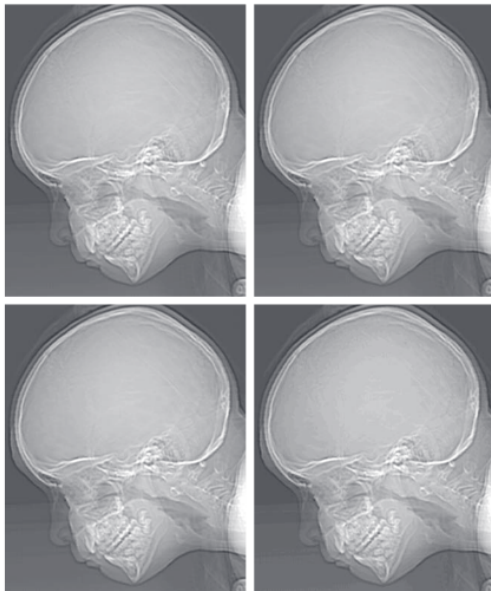


# Intensity resolution

a b  
c d

**FIGURE 2.24**

(a)  $774 \times 640$ , 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.)





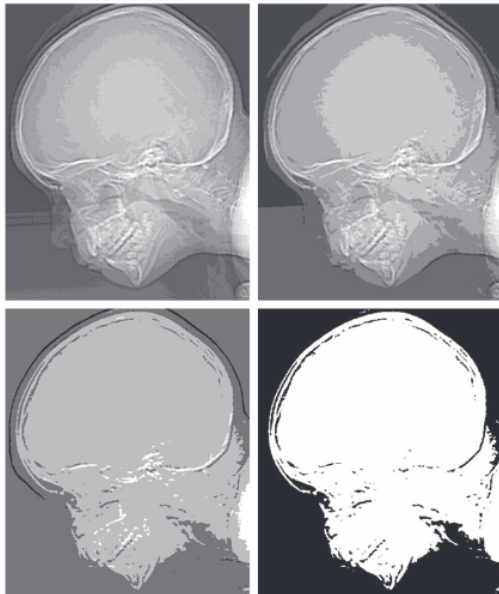
# Intensity resolution

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

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

## Relationships between pixels – Adjacency

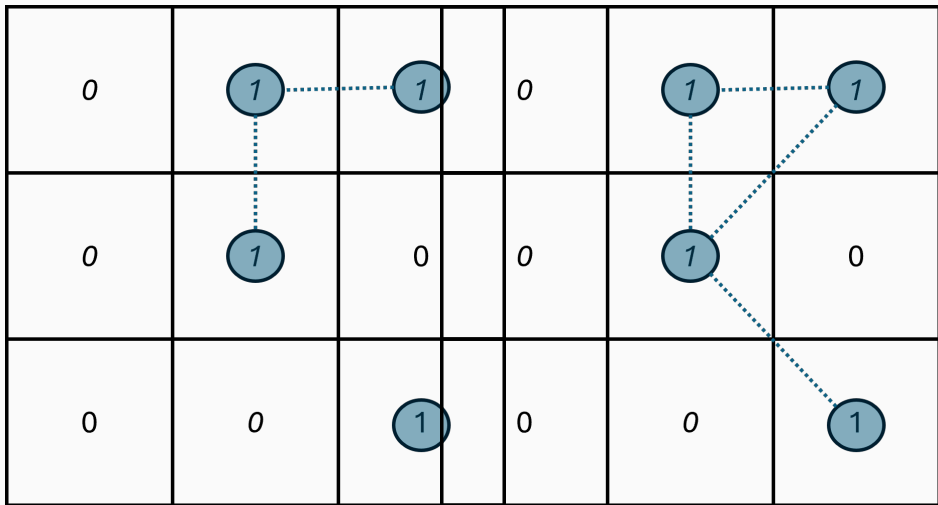
### 💡 Rules for adjacency

- 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:

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