Digital Image Processing Fundamentals

تبسيط أساسيات معالجة الصور الرقمية

1. Image Transformation Basics

Sampling (التقطيع)

Capturing the analog image at discrete points (e.g., a grid of pixels).

Quantization (التكميم)

means turning image colors or brightness into simple numbers

2. Storage Size Calculation (حساب مساحة التخزين)

The number of bits (b) required to store a digital image is calculated using:

$$b = M * N * k \text{ (bits)}$$

Key:

- **M** (Pixel) : Number of image rows
- **N** (Pixel) : Number of image columns
- **k** (Bit) : Bits per pixel

Example:

For an image of 1024×768 pixels, and k = 8 bits (256 gray levels):

1. **Total bits:** 1024 × 768 × 8 = 6,291,456 bits
2. **Total bytes:** 6,291,456 ÷ 8 = 786,432 bytes
3. **In kilobytes:** 786,432 ÷ 1024 ≈ 768 KB

3. Basic Relationships Between Pixels

Neighbors of pixel p = (x, y):

$N_4(p)$ → 4-neighbors

(horizontal & vertical)

```
. X .
X C X
. X .
```

$N_D(p)$ → Diagonal neighbors

(diagonal only)

```
X . X
. C .
X . X
```

$N_8(p)$ → 8-neighbors

($N_4 \cup N_D$)

```
X X X
X C X
X X X
```

Region / Connected Component
Set of pixels connected (by chosen adjacency) forming a single region.

Boundary / Contour
Pixels that separate a region from background.

4. Interpolation

is the process of estimating the values of new pixels that were not originally sampled, based on the values of surrounding pixels. It is mainly used in operations such as **resizing (zooming/shrinking)** or **rotating** an image.

Classification of Interpolation Methods

CATEGORY	DESCRIPTION	EXAMPLES
Spatial Interpolation	Estimates pixel values at new positions not directly sampled.	`Nearest, Bilinear, Bicubic`
Intensity Interpolation	Smooths or refines intensity values between quantized levels.	–

The Three Basic Spatial Interpolation Methods

Original Grid (الجدول الأصلي)

سنستخدم هذا الجدول 3x3 كأساس للأمثلة التالية:

10	20	30
40	50	60

70	80	90

🟩 Nearest-Neighbor Interpolation

الفكرة: كل بكسل جديد يأخذ نفس قيمة أقرب بكسل أصلي له.

Step 1 → Double the columns:

10	**10**	20	**20**	30
40	**40**	50	**50**	60
70	**70**	80	**80**	90

Step 2 → Double the rows:

10	10	20	20	30
10	**10**	**20**	**20**	**30**
40	40	50	50	60
40	**40**	**50**	**50**	**60**
70	70	80	80	90

🟢 **Result: Fast enlargement but with blocky (pixelated) edges.**

🟧 Bilinear Interpolation

الفكرة: البكسل الجديد = متوسط موزون بين الجيران (يمين/شمال + فوق/تحت).

Step 1 → Double the columns:

10	**15**	20	**25**	30
40	**45**	50	**55**	60
70	**75**	80	**85**	90

Step 2 → Double the rows:

10	15	20	25	30
25	**30**	**35**	**40**	**45**
40	45	50	55	60
55	**60**	**65**	**70**	**75**
70	75	80	85	90

🟠 **Result: Smoother than nearest-neighbor, but slightly blurred.**

🟦 Bicubic Interpolation

الفكرة: نستخدم 8 بكسلات (أو 16) حول النقطة الجديدة، ونحسب منحنى ناعم.

Resulting grid (after bicubic smoothing):

10	14	20	26	30
24	28	34	40	44
40	44	50	56	60
56	60	66	72	76
70	74	80	86	90

🔵 **Result: Very smooth and visually appealing with preserved edges.**

5. Distance Measures

Used to measure the distance between two pixels in an image.

1 Euclidean Distance

(المسافة الإقليدية)

The straight-line distance (shortest path).

```
2.83 2.24 2.00 2.24 2.83
2.24 1.41 1.00 1.41 2.24
2.00 1.00  P   1.00 2.00
2.24 1.41 1.00 1.41 2.24
2.83 2.24 2.00 2.24 2.83
```

$$D_e(p, q) = \sqrt{((x_1 - x_2)^2 + (y_1 - y_2)^2)}$$

2 City-Block

(مسافة كتلة المدينة)

Moves only along grid lines (no diagonal).

```
4 3 2 3 4
3 2 1 2 3
2 1 P 1 2
3 2 1 2 3
4 3 2 3 4
```

$$D_4(p, q) = |x_1 - x_2| + |y_1 - y_2|$$

3 Chessboard

(مسافة رقعة الشطرنج)

Allows diagonal movement (like a King).

```
2 2 2 2 2
2 1 1 1 2
2 1 P 1 2
2 1 1 1 2
2 2 2 2 2
```

$$D_8(p, q) = \max(|x_1 - x_2|, |y_1 - y_2|)$$

Example: p=(0,0), q=(2,1)

Summary (الملخص)

(Δx = 2, Δy = 1)

Type	Formula	Result
Euclidean	√(2²+1²)	≈ 2.236
City-Block	2 + 1	3
Chessboard	max(2,1)	2

Type	Formula	Movement
Euclidean	√(Δx²+Δy²)	Any
City-Block	|Δx|+|Δy|	Horiz/Vert
Chessboard	max(|Δx|,|Δy|)	Any (diag)

6. Dynamic Range, Contrast, and Histogram

Dynamic Range

Range of possible intensity values (brightness span).

$$DR = I_{max} / I_{min}$$

Contrast

Difference between brightest and darkest areas.

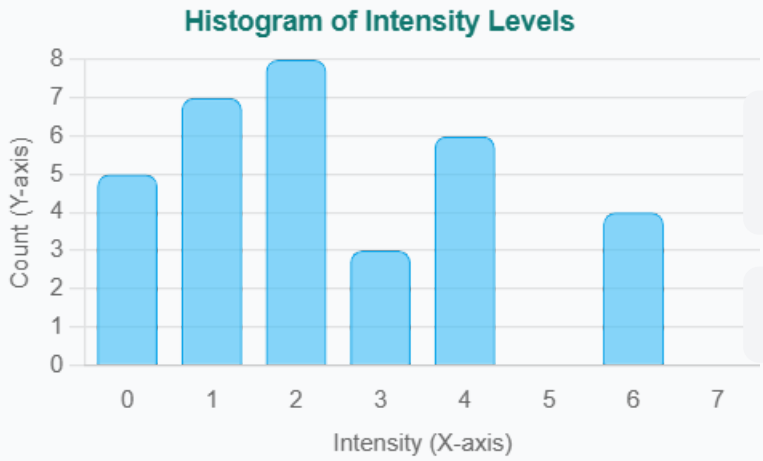
$$C = I_{max} - I_{min}$$

Histogram

Graph showing the frequency of each intensity value.

- **X-axis:** Intensity level
- **Y-axis:** Number of pixels

Histogram Example (مثال) h = { 5, 4, 3, 0, 1, 6, 3, 2, 4, 2, 1, 0, 5, 0, 2, 4, 4, 1, 2 }



Low contrast: Most values in the middle.

High contrast: Values at both ends.