

Chapter -3 Digital Image Noise

Noise is defined as unwanted information that can appear in the signal and lead to its distortion.

➤ Signal types:-

a- Electrical signal

b- Audio signal

c- Two-dimensional signal (image)

(3-1) Noise Models

The presence of noise in images distorts them, which makes analyzing them a difficult process. Therefore, studying noise helps a lot in knowing its effect on images or determining the optimal methods for removing it from images and recovering information about the image with minimal losses.

The types of noise can be classified mathematically as follows: -

- 1- Additive Noise
- 2- Multiplicative Noise
- 3- Salt and Pepper Noise
- 4- Sinusoidal Noise
- 5- Periodic Noise.

(3-1-1) Additive Noise

It is random noise that does not depend on the signal (**That is, its causes are external factors that have no relation to the real signal**), and its characteristics are as follows: -

- 1- It is white noise whose spectral intensity is constant throughout the image.



- 2- Statistical approximations of the additive noise distribution usually approach the Gaussian or uniform distribution.
- 3- Additive linearization in which the image obtained is an original image plus noise, and is given by the following relationship:-

$$I(x, y) = R(x, y) + n(x, y) \dots\dots\dots (2-8)$$

↓
↓
الضوضاء المضافة

الصورة المشوهة
(صفر الى 255) خالية من الضوضاء
نتيجة استطرارة او حرارة

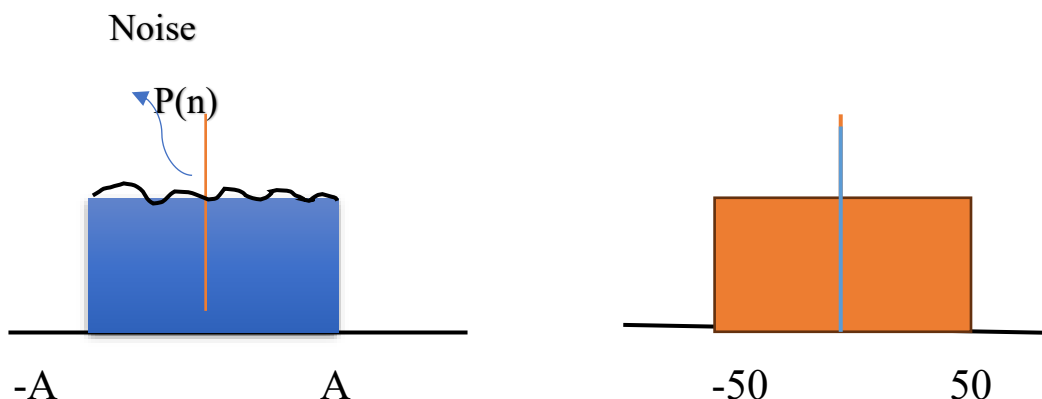
→ ∞
ومعدلها صفر وقيمتها بين (∞ ∞)

ملاحظة: - الضوضاء إذا نحن عملناها بالصورة تسمى محاكاة (Simulation)

There are two mathematical models for additive noise that can be represented as follows: -

a-Uniform Noise: -

This noise is caused by distorted signals with random values with regular frequencies and represents a distribution with equal probability for each value of the noise (n).



Each element has the same probability, and if the range of noise is increased, the image distortions also increase. Uniform noise has a mean of zero but has a standard deviation. This noise may appear in the television signal.

$$\sigma = \sqrt{\sum V^2 P(V) - (\sum V P(V))^2} \dots\dots(2-9)$$

R +(-50)

50	51	49	200					
52	50	53	201		0	1	-1	150
50	49	202	200		2	0	3	151
200	203	200	220		0	-1	152	150
					150	153	150	170

ملاحظة :- التكرارات في التوزيع المنتظم لها نفس القيمة (أي لها نفس التكرار لكن توزيعها عشوائي) أي ان تكرار العنصر لنفسه لكثافة العناصر .

ويستخدم مرشح (الفلتر) local Mean لإزالته.

$$\bar{I} = \bar{R} + \bar{n} \dots(2-10)$$

b -Gaussian Noise: -

This noise occurs due to the dispersion of electromagnetic waves in different directions, due to the presence of dust particles or particles of relatively small diameters present in the air. This noise is subject to a Gaussian distribution.

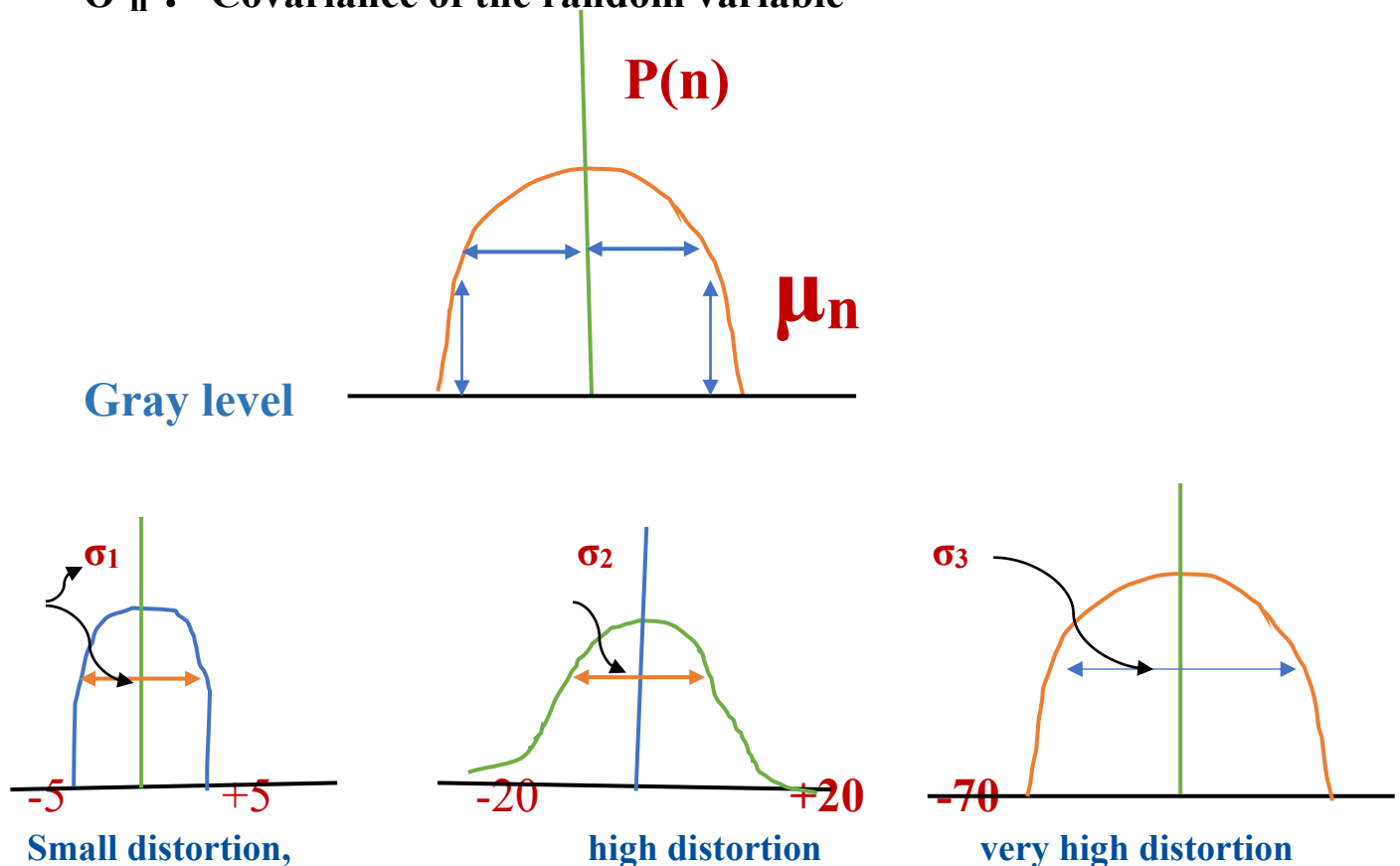
$$P(n) = \frac{1}{\sqrt{2\pi\sigma_n^2}} e^{-\frac{(n-\mu_n)^2}{2\sigma_n^2}} \dots\dots\dots(2-11)$$

where: -

n : - Random variable

μ_n :- The rate value of a random variable.

σ_n^2 :- Covariance of the random variable



- **Notice:** - 1- When the standard deviation of noise increases, the distortion in the image increases.
- 2- Gaussian noise is irregular; when we approach zero, the frequency increases.

(3-1-2) Multiplicative Noise: refers to an unwanted random signal that gets multiplied into some relevant signal during capture, transmission, or other processing.

or

It is random noise that depends on the signal, meaning that the bright areas in the image have high noise, and the lower the light intensity, the less noise. This means that the relationship between the amount of noise and intensity is smooth (linear) and this noise is characterized by: -

1- Estimates of the distribution of multiplicative noise often approach a chi-square distribution or a Poisson distribution.

2- The resulting images are an original image(R) multiplied by noise (F), as shown in the following mathematical formula: -

$$I = R + n(R)$$

$$I(x, y) = R(x, y) \cdot F(x, y) = R(x, y) + n R(x, y)$$

if it was $n R(x, y) = K(x, y) \longrightarrow = \text{constant}$

$$\therefore I(x, y) = R(x, y) + K(R(x, y))$$

$$I(x, y) = R(x, y) (1 + K)$$

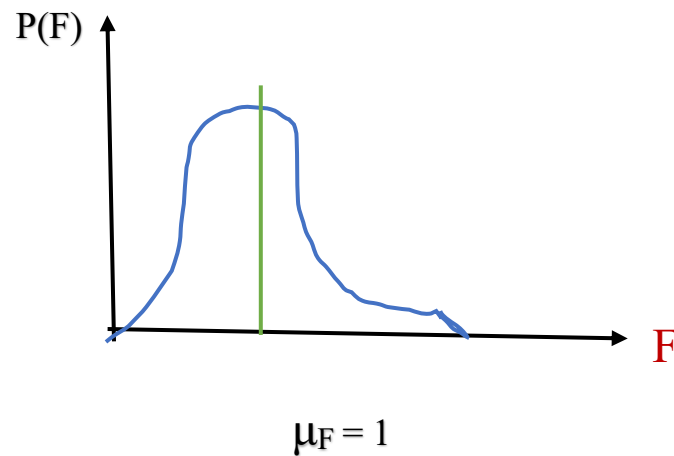
يعتمد على الموقع فقط لا يعتمد على الإشارة
بينما الضوضاء (KR) تعتمد على الإشارة (K=0)

متغير عشوائي لا يعتمد على الإشارة $F(x, y)$

$$\mu_F = 1, \quad \hat{F} = 1 \quad \text{المعدل}$$

في بعض المصادر يسمى $F(x, y)$ بالضوضاء لكنه متغير يعتمد على الموقع ولا يعتمد على الإشارة.

($F(x, y) > 1$) تعتبر ضوضاء إيجابية لأنها تكبر الإشارة.



There are two types of Multiplicative noise: -

a- Poisson Noise: -

Its reason is due to the quantum nature of photons, so it is sometimes called quantum noise or photonic noise. This noise distorts images taken with **photonic imaging systems**, such as X-ray imaging, and is also present in **low illuminance**.

b- Speckle noise (النقطية البقعية، الرقمية) (Distribution Square – Chi., X^2)

is a form of noise that commonly occurs in images acquired through coherent imaging techniques such as ultrasound imaging, synthetic aperture radar (SAR), and Laser imaging systems hologram systems are systems that produce low-quality images due to speckle noise. Unlike Gaussian noise or salt and pepper noise, which manifest as additive disturbances, speckle noise is multiplicative in nature.

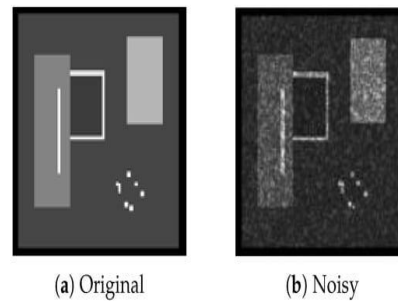


Fig. (3-1) Original image and simulated noisy image.

This noise is normalized by the cosine function (cos)

$$I(x, y) = 255 \cos(\pi/2 * I(x, y)/255)$$

.....

The difference between additive and multiplicative noise

5	100
41	101

 $+$

-5	4
10	-11

 $\longrightarrow$

0	104
51	90

5	100
41	101

 $+$

2	4
10	2

 $\longrightarrow$

0	400
410	202

255

5	100
41	101

 $*$

2	4
10	2

 $\longrightarrow$

0	400
410	202

255

ملاحظة مهمة: - لا يوجد F بقيمة سالبة.

$$F = 0 \longrightarrow 255, \text{ the mean of } F = 1$$

$$R(x, y) = 0 \longrightarrow 255$$

ملاحظة: - في بعض الأحيان بدلا من تحويل القراءة لاي قيمة اعلى من 255 الى 255 بأخذ الجذر التربيعي لان اعلى قيمة ل $(255)^2$ هي 255 .

0	10	0
---	----	---

5

5	15	5
---	----	---

+

=

يلاحظ ان الضوضاء الجمعية هي ضوضاء بيضاء يظهر تأثيرها المنظم في جميع المناطق.

0	10	200
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5

0	50	1000
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*

=

 $n(R_0) \quad n(R_1) \quad n(R_2)$

$$n(R_i) = I - R_i$$

=

0	40	800
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∴ الضوضاء الضربية في مناطق الشدة الواطنة تكون قليلة، اما في مناطق الشدة العالية تكون عالية.

(3-1-3) Salt and Pepper Noise: -

In some imaging or image scanning systems, a change in intensity and location occurs, which distorts the resulting image, and this distortion is in the form of points randomly distributed across the image plane. This noise is of two types: -

Salt Noise: represented by white points. $A = 255$

Pepper Noise: represented by black points. $A = 0$

The main reason for generating this noise is the presence of large particles located at a distance between the light source and the imaging or image-scanning device.

The best way to remove this noise is to use the median and mode method.

This noise is sometimes called **Replacement Noise**.

(3-1-4) Periodic noise

It falls within the multiplicative noise and is not random. It occurs when scanning the image (scanner) due to irregularity in the intensity distribution of illumination when scanning, as in electrical devices.

(3-1-5) Sinusoidal noise

The image contains two types of noise, one of which depends on the signal (multiplicative noise) and the other does not depend on the signal (additive noise).

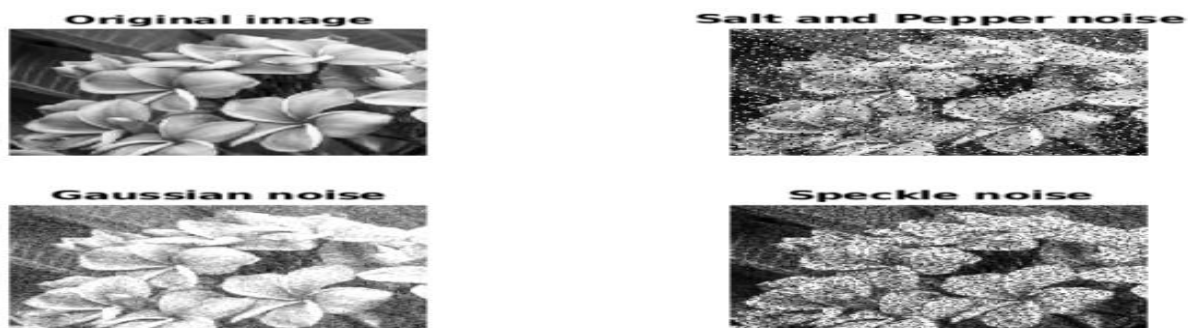


Fig. (3-2) Types of Noises