2.3.3 Acquisition Noise and How to Estimate It

Let us briefly touch upon the problem of *noise* introduced by the imaging system and how it is estimated. The effect of noise is, essentially, that image values are not those expected, as these are corrupted during the various stages of image acquisition. As a consequence, the pixel values of two images of the same scene taken by the same camera and in the same light conditions are never *exactly* the same (try it!). Such fluctuations will introduce errors in the results of calculations based on pixel values; it is therefore important to estimate the magnitude of the noise.

The main objective of this section is *to suggest a simple characterization of image noise*, which can be used by the algorithms of following chapters. Noise attenuation, in particular, is the subject of Chapter 3.

An obvious way to proceed is to regard noisy variations as random variables, and try to characterize their statistical behavior. To do this, we acquire a sequence of images of the same scene, in the same acquisition conditions, and compute the pointwise average of the image brightness over all the images. The same sequence can also be used to estimate the *signal-to-noise ratio* of the acquisition system, as follows.[8]

Algorithm EST_NOISE

We are given n images of the same scene, $E_0, E_1, \ldots, E_{n-1}$, which we assume square ($N \times N$) for simplicity.

For each $i, j = 0, \ldots, N-1$, let

$$\overline{E(i,j)} = \frac{1}{n}\sum_{k=0}^{n-1} E_k(i,j)$$

$$\sigma(i,j) = \left(\frac{1}{n-1}\sum_{k=0}^{n-1}\left(\overline{E(i,j)} - E_k(i,j)\right)^2\right)^{\frac{1}{2}} \tag{2.17}$$

The quantity $\sigma(i,j)$ is an estimate of the standard deviation of the acquisition noise at each pixel. The average of $\sigma(i,j)$ over the image is an estimate of the average noise, while $\max_{i,j\in[0,\ldots,N-1]}\{\sigma(i,j)\}$ an estimate of the worst case acquisition noise.

☞ Notice that the beat frequency of some fluorescent room lights may skew the results of EST_NOISE.

Figure 2.11 shows the noise estimates relative to a particular acquisition system. A static camera was pointed at a picture posted on the wall. A sequence of $n = 100$ images was then acquired. The graphs in Figure 2.11 reproduce the average plus and minus

[8] The signal-to-noise ratio is usually expressed in *decibel* (dB), and is defined as 10 times the logarithm in base 10 of the ratio of two powers (in our case, of signal and noise). For example, a signal-to-noise ratio of 100 corresponds to $10\log_{10}100 = 20dB$.