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All image systems have limits to their resolution: a point source gives rise to a small blur spot. The effect is that images are smoothed: components with higher spatial frequencies are attenuated. Indeed, above some frequency signals are completely lost; in a good optical system this corresponds to the diffraction limit, in a poor one the limit will be lower. One can attempt to "restore" image components below this limit by amplifying some frequencies, undoing the attenuation introduced by the imaging system.

Unfortunately, all image brightness measurements are also corrupted by noise. Noise is amplified with the signal when the "restoring" procedure is applied. Typically the noise in brightness measurements made at different points is independent; the spatial spectrum of noise is flat. After the filtering operation however one finds a non-uniform spectrum. Low frequencies are passed through, higher frequencies are amplified; frequencies near and above the absolute resolution limit of the imaging system are attenuated.

Noise in the "restored" picture thus is (roughly) band-pass; it is spatially coherent. What does band-pass noise look like? Band-pass noise tends to have bumps and wrinkles of a size commensurate with waves at the spatial frequencies which have been amplified most. Images of band-pass noise have a dimpled, mottled, convoluted, "wormy" character, a little like the cortex of the brain or close-up pictures of orange peel.

Such effects can be seen also in tomographic reconstructions, where convolutional filters accentuate higher frequencies in noisy measurements of beam absorption (1). This is unavoidable since the projection process in effect attenuates these higher frequencies; the reconstruction algorithm then must undo this selective filtering by a process vaguely similar to differentiation; actually Hilbert transformation.

Recently researchers have become more aware of the "unstable" or "ill-conditioned" nature of the image restoration problem (2). It is acknowledged that severe "error propagation" can occur.

Band-pass noise effects are most noticable when the image is oversampled, that is, has been specified on a grid of points spaced more closely than the basic resolution of the imaging system. If image sampling matches the resolution, the coherence of noise is less noticable, and the appearance is more like that of independent noise with which everyone is familiar.

Images containing band-pass noise can be misinterpreted. A number of "features" seen in restored pictures of Ganymede taken by Pioneer 10 (3), for example, are mere undulations in the band-pass noise resulting from the "restoring" process. In particular, three round details, seen in figure 5 of that paper, claimed to be maria, fall in this category. These "features" do not match any of the surface markings apparent in pictures of Ganymede taken by Voyager 1 and 2 (4-7). The area concerned lies in a large dark cap-like region and does not differ substantially from other parts of the same region. The results of such image alterations must obviously be interpreted with care.

In fact, image enhancement infrequently shows features which are not visible in a well prepared transparency of the original image. Spatial frequencies above the cutoff of the imaging system cannot be restored in any case; lower frequency signals stand in the same ratio to noise before and after "enhancement".

At times the dynamic range of the image is reduced by removing low frequency components. Conversely the contrast of higher frequency components can be increased given the same dynamic range. This, in a sense, is overdoing the "restoration" process; or perhaps applying it to an image which was not degraded in the first place.

Reducing low frequency components has serious side effects since it reduces the shading apparent on smoothly curved surfaces. We use this important depth-cue to recover the shape of objects (8). When we cannot recover the shape, it becomes difficult to assign significance to the brightness patterns we do perceive. Are they the result of spatial variations in the reflective properties of the surface or are they the result of differences in surface orientation? Conversely one may see a bump in brightness distribution due to band-pass noise as a "crater".

Image processing methods allow one to fit the information of interest into the very limited dynamic range of the printed page. The spatial resolution and density resolution of a half-tone print is very much worse than that of a piece of film. The image can be processed to bring the features of interest into the useable reproduction range of available printing methods. This is where the real utility of image processing methods lies.

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