Image processing: A quick reference sheet for the exam

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Contents

1 Introduction

This document is done in order to describe the general concepts that has been covered in the course, and also provide answers to some common exam questions. The content is shamelessly ripped from various sources, which is indicated at the start of a section or paragraph. Feel free to add sections, figures and answers to exams.

Guide:

[**W**] Wikipedia

[**L**] Lecture notes

[**E**] Exam

[**B**] Course Book

[**O**] Other

None Missing or anecdotal

2 Noise

2.1 General concepts

2.1.1 What is noise?

[W] Image noise is random (not present in the object imaged) variation of brightness or color information in images, and is usually an aspect of electronic noise. It can be produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is an undesirable by-product of image capture that adds spurious and extraneous information.

The original meaning of "noise" was and remains "unwanted signal"; unwanted electrical fluctuations in signals received by AM radios caused audible acoustic noise ("static"). By analogy unwanted electrical fluctuations themselves came to be known as "noise". Image noise is, of course, inaudible.

The magnitude of image noise can range from almost imperceptible specks on a digital photograph taken in good light, to optical and radioastronomical images that are almost entirely noise, from which a small amount of information can be derived by sophisticated processing (a noise level that would be totally unacceptable in a photograph since it would be impossible to determine even what the subject was).

2.2 Various types of noise

2.2.1 White additive gaussian noise

TODO

2.2.2 Salt and pepper noise

[W] Salt-and-pepper noise is a form of noise sometimes seen on images. It presents itself as sparsely occurring white and black pixels. An effective noise reduction method for this type of noise is a **median filter** or a morphological filter. For reducing either salt noise or pepper noise, but not both, a contraharmonic mean filter can be effective.

2.2.3 Gaussian noise

[W] Gaussian noise is statistical noise having a probability density function (PDF) equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed.

2.2.4 Additive

TODO

2.2.5 Multiplicative

In signal processing, the term multiplicative noise refers to an unwanted random signal that gets multiplied into some relevant signal during capture, transmission, or other processing.

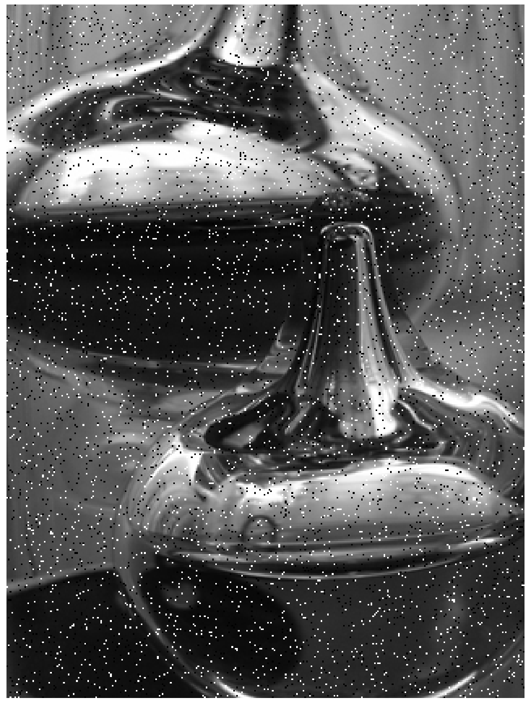

Figure 1: Example of salt and pepper noise

2.2.6 Exponential

TODO

2.3 Colors of noise

2.3.1 White noise

[W] White noise is a signal (or process), named by analogy to white light, with a flat frequency spectrum when plotted as a linear function of frequency (e.g., in Hz). In other words, the signal has equal power in any band of a given bandwidth (power spectral density) when the bandwidth is measured in Hz.

2.3.2 Pink noise

TODO

2.3.3 Blue noise

[W] In computer graphics, the term "blue noise" is sometimes used more loosely as any noise with minimal low frequency components and no concentrated spikes in energy. This can be good noise for dithering.

3 Filters

3.1 Median filter

3.1.1 Description

[W] In signal processing, it is often desirable to be able to perform some kind of noise reduction on an image or signal. The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise.

3.1.2 Algorithm description

[O] Like the mean filter, the median filter considers each pixel in the image in turn and looks at its nearby neighbors to decide whether or not it is representative of its surroundings.

Instead of simply replacing the pixel value with the mean of neighboring pixel values, it replaces it with the median of those values. The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value. (If the neighborhood under consideration contains an even number of pixels, the average of the two middle pixel values is used.)

Why use median instead of mean:

- The median is a more robust average than the mean and so a single very unrepresentative pixel in a neighborhood will not affect the median value significantly.

- Since the median value must actually be the value of one of the pixels in the neighborhood, the median filter does not create new unrealistic pixel values when the filter straddles an edge. For this reason the median filter is much better at preserving sharp edges than the mean filter.

3.2 Mean filter

[O] The idea of mean filtering is simply to replace each pixel value in an image with the mean ('average') value of its neighbors, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings.

Problems with mean filtering:

- A single pixel with a very unrepresentative value can significantly affect the mean value of all the pixels in its neighborhood.
- When the filter neighborhood straddles an edge, the filter will interpolate new values for pixels on the edge and so will blur that edge. This may be a problem if sharp edges are required in the output.

Both of these problems are tackled by the median filter, which is often a better filter for reducing noise than the mean filter, but it takes longer to compute.

4 Image sharpening

TODO

4.1 Edge detection

TODO

4.2 High Boosting

TODO

5 Image histograms

5.1 Histogram equalization

[W] This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

The method is useful in images with backgrounds and foregrounds that are both bright or both dark. In particular, the method can lead to better views of bone structure in x-ray images, and to better detail in photographs that are over or under-exposed. A key advantage of the method is that it is a fairly straightforward technique and an invertible operator. So in theory, if the histogram equalization function is known, then the original histogram can be recovered. The calculation is not computationally intensive. A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal.

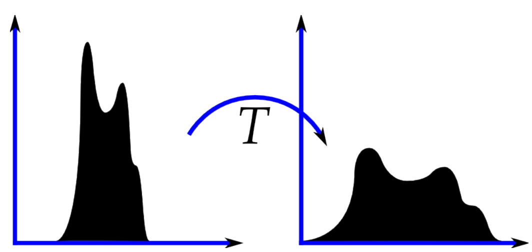

Figure 2: Example of histogram equalization

5.1.1 The idea behind histogram equalization

[L] Our eyes (brain) can see more details if the image histogram is wide and approximately flat, rather than narrow and peaked.

5.1.2 Example: How to equalize a histogram in practice

[E] Assume you have a 2-bit image like this:

$$\begin{bmatrix} 1 & 1 & 2 & 2 \\ 2 & 1 & 3 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 2 & 2 & 1 \end{bmatrix} \tag{1}$$

How do you equalize its histogram?

Answer: Create a table like table 1. Then simply create the new equalized image by replacing the original values with the new values:

Orig. Value	Probability	Cum. prob.	Rounded	New Value
0	1/16	1/16	0/3	0
1	9/16	10/16	2/3	2
2	5/16	15/16	3/3	3
3	1/16	16/16	3/3	3

Table 1: Histogram equalization table

$$\begin{bmatrix} 2 & 2 & 3 & 3 \\ 3 & 2 & 3 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 3 & 3 & 2 \end{bmatrix} \tag{2}$$

This is the new equalized image. This histogram is poorly equalized due to small number of both bits and pixels.

5.1.3 Histogram equalization of a one-color image

Assume you equalize a histogram of an image of just one colour. As the probability will reach maximum at that gray value, the cumulative and rounded value will as well. Thus all original values will be replaced with the maximum gray value (white).

5.2 Histogram matching

[W] Histogram matching is a method in image processing of color adjustment of two images using the image histograms.

It is possible to use histogram matching to balance detector responses as a relative detector calibration technique. It can be used to normalize two images, when the images were acquired at the same local illumination (such as shadows) over the same location, but by different sensors, atmospheric conditions or global illumination.

6 Wavelets

TODO

7 Image compression

TODO

8 Old exams

TODO