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IMAGE NOISE REDUCTION THROUGH SPLINE SMOOTHING

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ABSTRACT: Noise reduction is an essential part of image processing and there are many algorithms for the noise reduction process however, the common problem is that the noise reduction makes the contours unclear or leaves noise on the edges. All recording devices, both analog and digital have traits that make them susceptible to noise. Noise can be random or white noise with no coherent noise introduce by the device's mechanism or processing algorithms. In this paper by spline smoothing we have tried to reduce image noise. By using this method we can minimize mean square error by determining the trade off values and weight coefficients for each line and pixel effectively.

KEY WORDS: : Noise Reduction, Mean square error, spline interpolation.

INTRODUCTION

Noise reduction is the process of removing noise from a signal. Image can be taken with both digital cameras and conventional film cameras will pick up noise from a variety of sources. Further use of this image will often require that the noise be removed for aesthetic purposes as in artistic work or marketing, or for practical purposes such as computer vision. The noise reduction process can make image smooth; on the other hand to distinguish the edges from the noise. It is important to minimize the mean square error (MSE) in the noise reduction process, it is also necessary that the MSE of the magnitude of the gradient vectors is minimized to keep the edges sharp. In this paper I considered a method which reduces noise and keep the edges sharp using spline smoothing. Direct spline interpolation of noisy data may result in a curve with unwanted oscillations.

VARIOUS SOURCES OF NOISE IN IMAGE

Noise is introduced in the image at the time of image acquisition or transmission. Different factors may be responsible for introduction of noise in the image. The number of pixels corrupted in the image will decide the quantification of the noise. The principal sources of noise in the digital image are: a) The imaging sensor may be affected by environmental conditions during image acquisition. b)Insufficient Light levels and sensor temperature may introduce the noise in the image. c) Interference in the transmission channel may also corrupt the image. d) If dust particles are present on the scanner screen, they can also introduce noise in the image.

TYPES OF NOISE

Noise is the undesirable effects produced in the image. During image acquisition or transmission, several factors are responsible for introducing noise in the image. Depending on the type of disturbance, the noise can affect the image to different extent. Generally our focus is to remove certain kind of noise and apply different algorithm to remove the noise.

1. SALT AND PEPPER NOISE (IMPULSE NOISE)

Fat-tail distributed or “impulsive” noise is sometimes called salt and pepper noise or spike noise. An image containing salt and pepper noise will have dark pixels in bright regions and bright pixels in dark regions. In salt and pepper noise (sparse light and dark disturbances), pixels in the image are very different in color or intensity from their surrounding pixels; the defining characteristic is that the value of a noisy pixels bears no relation to the color of surrounding pixels. Generally this type of noise will only affect a small number of pixels. When viewed, the image contains dark and white dots, hence the term salt and pepper noise. This type of noise can be caused by analog to digital converter errors, bit error in transmission etc.

2. GAUSSIAN NOISE (AMPLIFIER NOISE)

Principal sources of Gaussian noise in digital images arise during acquisition. The sensor has inherent noise due to the level of illumination and its own temperature, and the electronic circuits connected to the sensor inject their own share of electronic circuit noise. In Gaussian noise, each pixel in the image will be charged from its original value by a (usually) small amount. A histogram, a plot of the amount of distortion of a pixel value against the frequency with which it occurs, shows a normal distribution of noise. While other distributions are possible, the Gaussian (normal) distribution is usually a good model, due to the central limit theorem that says that the sum of different noises tends to approach a Gaussian distribution. In either case, the noise at different pixels can be either correlated or uncorrelated; in many cases, noise values at different pixels are modeled as being independent and identically distributed, and hence uncorrelated.

3. SHOT NOISE

The dominant noise in the darker parts of an image from an image sensor is typically that caused by statistical quantum fluctuations, that is, variation in the number of photons sensed at a given exposure level. This noise is known as photon shot noise. Shot noise has a root mean square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. Shot noise follows Poisson distribution which expect at very low intensity levels approximates a Gaussian distribution.

In addition to photon shot noise, there can be additional shot noise from the dark leakage current in the image sensor; this noise is sometimes known as “dark shot noise” or “dark-current shot noise”. Dark current is greatest at “hot pixels” within the image sensor. The variable dark charge of normal and hot pixels can be subtracted off (using “dark frame subtraction”), leaving only the shot noise, or random component, of the leakage. If dark frame subtraction is not done, or if the exposure time is long enough that the hot pixel charge exceeds the linear charge capacity, the noise will be more than just shot noise, and hot pixels appear as salt and pepper noise.

4. QUANTIZATION NOISE (UNIFORM NOISE)

The noise caused by quantizing the pixels of a sensed image to a number of discrete levels is known as quantization noise. It has an approximately uniform distribution. Through it can be signal dependent, it will be signal dependent, it will be signal independent if other noise sources are big enough to cause dithering, or if dithering is explicitly applied.

5. FILM GRAIN

The grain of photographic film is a signal-dependent noise, with similar statistical distribution to shot noise. If film grains are uniformly distributed (equal number per area), and if each has an equal and independent probability of developing to a dark silver grains after absorbing photons, then the number of such dark grains in an area will be random with a binomial distribution. In areas where the probability is low, this distribution will be close to the classis Poisson distribution of shot noise. A simple Gaussian distribution is often used as an accurate model.

Film grain is usually regarded as a nearly isotropic (non-oriented) noise source. Its effect is made by the distribution of silver halide grains in the film also being random**.**

6. ANISOTROPIC NOISE

Some noise sources show up with a significant orientation images. For example, image sensors are sometimes subject to row noise or column noise.

7. PERIODIC NOISE

A common source of periodic noise in an image is from electrical or electromechanical interference during the image capturing process. An image affected by periodic noise will look like a repeating pattern has been added on top of the original image. In the frequency domain this type of noise can be seen as discrete spikes. Significant reduction of this noise can be achieved by applying notch filters in the frequency domain. The following images illustrate an image affected by periodic noise, and the result of reducing the noise using frequency domain filtering. Note that the filtered image still has some noise on the borders. Further filtering could reduce this border noise. However it may also reduce some of the fine details in the image. The trade-off between noise reduction and preserving fine details is application specific. For example if the fine details on the castle are not considered important, further low pass filtering could be an appropriate option. If the fine details of the castle are considered important, a viable solution may be to crop off the border of the image entirely.

REMOVING NOISE FROM IMAGE BY SPLINE SMOOTHING

Here I start over with a completely different rationale for smoothing. I am not going to use anything remotely resembling a kernel or “local” use of any well-known statistical procedure. I have used a completely different approach of using penalty functions. The method of least square at finds the best model within a certain parametric class to fit the data. But if the parametric class is too big (generally, whenever there are at least as many parameters as data points) we just fit the data perfectly.

One cure is to “penalize” models that seem less reasonable. The penalty function that leads to smoothing splines penalizes integrated squared second derivative. The method of smoothing splines chooses that g that minimizes “residual sum of squares plus penalty”

$$\sum_{i=1}^{n}[y_i - g(x_i)]^2 + \lambda \int_{-\infty}^{\infty} g''(x)^2 dx \tag{1}$$

Spline smoothing criterion function:

$$E = \alpha \sum_{i=1}^{n}[y_i - g(x_i)]^2 + (1-\alpha) \int_{-\infty}^{\infty} g''(x)^2 dx$$

Where λ is a fix positive number, called the smoothing parameters that plays the role that bandwidth plays in kernel smoothing. In the above criterion function α is a tradeoff value between fitting and smoothing and W_i are weight coefficients of i[th] data.

It can be shown that the g that minimize $W_i$es (1) is always a natural cubic spline with knots at the observed predictor values. Cubic spline is a standard mathematical function commonly used to interpolate a data set. Let $x_{(1)},\ldots\ldots,x_{(k)}$ be the distinct ordered predictor values, that is, each x_i is some $x_{(j)}$ and

$$x_{(1)} < x_{(2)} < \cdots < x_{(k)}$$

Then a natural cubic spline has following properties.

- On each interval between knots ($x_{(j)}, x_{(j+1)}$) the function g is cubic

$$g(x) = \alpha_j + \beta_j x + \gamma_j x^2 + \delta_j x^3, \qquad x_{(j)} < x < x_{(j+1)}$$

- On each semi infinite interval outside the knots the function g is linear

$$g(x) = \alpha_0 + \beta_0 x, \qquad x < x_{(1)}$$
$$g(x) = \alpha_k + \beta_k x, \qquad x > x_{(k)}$$

- This specifies g by 4k parameters (α’s, β’s, γ's, and δ's).
- At knots g, g' and $g''$are continuous
- This imposes 3k conditions, which are equations that are linear in the parameters. Hence the 4k original parameters can be expressed as linear function of k free parameters.

This has the following important consequence functions. The functions g and g'' are linear in the parameters. Thus the penalized least squares objective function (1) is quadratic in the parameters. To minimize a quadratic function, one find a point where all the partial derivatives are zero. All partial derivatives of (1) are linear in the parameters. Hence the minimization is carried out by solving linear equations. Moreover, all partial derivatives of (1) are also linear in the data. Thus the penalized least squares estimates are linear functions of the data vector $y = (y_1, \ldots\ldots, y_{n)}$ and so is the predicted value vector ŷ because $g(x)$ is linear in the parameters.

As we adjust λ between zero and infinity the smoothing spline goes from very rough to very smooth. At $\lambda = \infty$ we only have (1) finite if the integral is zero, which happens only if $g''(x) = 0$ for all x, which happens only if $g(x)$ is a linear function. Thus this case is the same as simple linear regression. At $\lambda = 0$ the smoothing spline interpolates the data.

To achieve the desire result we add Gaussian noise in data image. Apply spline smoothing to the noisy data and obtain the gradian matrix. Decide new values of α and W for each line and pixel. The smaller this value the smoother the image will be.

ALGORITHM OF IMAGE NOISE REDUCTION USING SPLINE

- Consider and image as an original image
- Convert it to gray scale
- Add Salt & Pepper noise to the input noise
- Apply Spline smoothing on the noisy image
- Calculate the mean square error
- Noiseless image is obtained as an output after removing noise through spline.

EXPERIMENTAL RESULT:

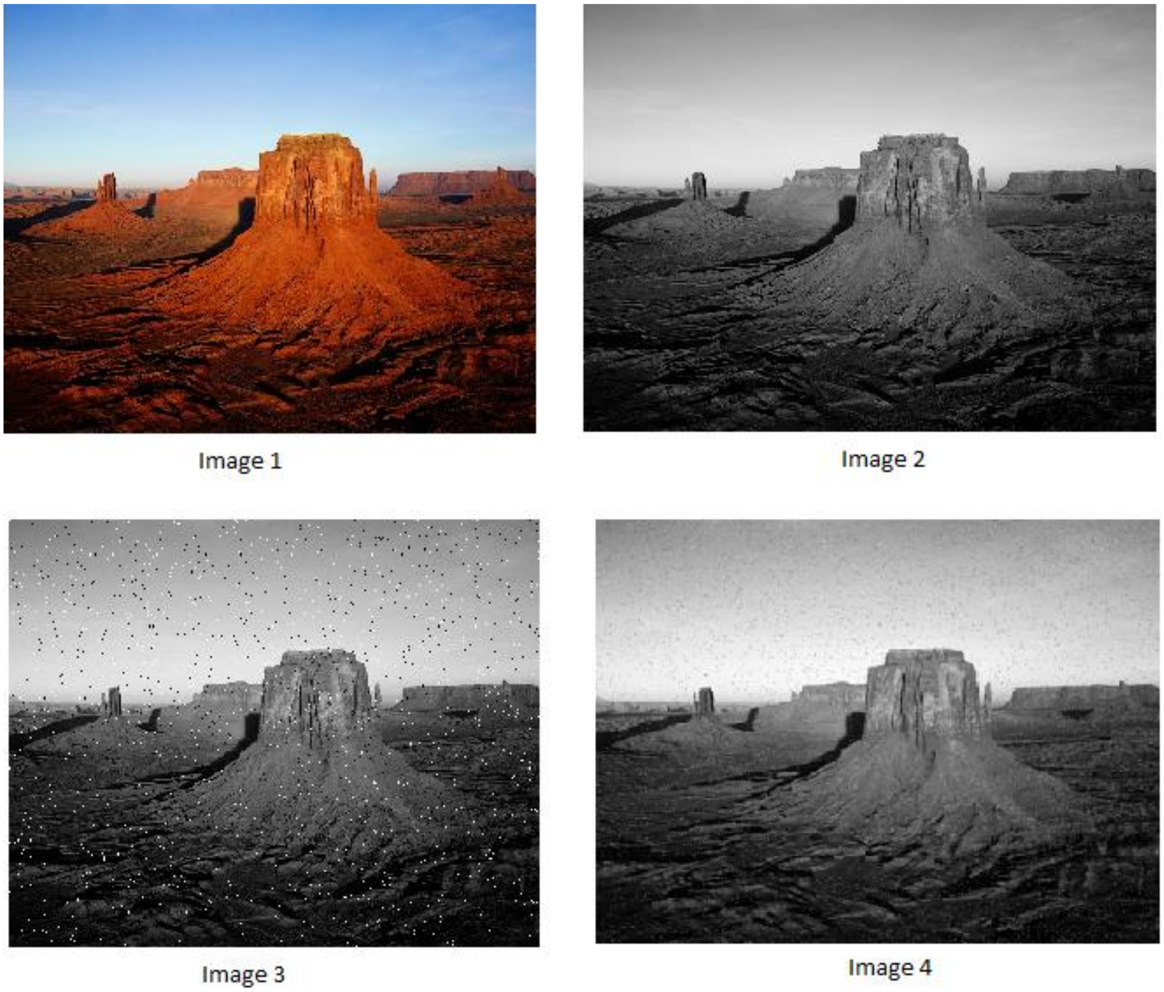

Image 1- Original Image, Image 2- Conversion to gray scale,

Image 3- Addition of salt-pepper noise, Image 4- Final result

Fig.4.12.1 Result of Image Noise Reduction using Spline Smoothing

- **MSE** value calculated is **390.7358** while the **PSNR** value calculated is **22.2120**

CONCLUSION

The method using spline smoothing can minimize MSE by determining the trade-off value and weight coefficient for each line and pixel effectively. By using spline smoothing tool we are successfully able to remove noise and we get smooth and noiseless. Here as a result which image we get it is little blur and also this method should be improved to reduce the running cost.

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