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Image Filtering Algorithms and Techniques: A Review

Ruchika Chandel, Gaurav Gupta
Computer Science Department
Shoolini University (H.P), India

Abstract: -This paperdescribes the various image filtering algorithms and techniques used for image filtering/smoothing. Image smoothing is one of the most important and widely used operation in image processing .We have explained various algorithms and techniques for filter the images and which algorithm is the be the best for smoothing and filtering the images, especially we have mainly concentrate on non-linear filtering algorithms i.e. median filtering is very important in edge preserving. The image may be corrupted by random variations in intensity, variations in illumination or poor contrast that may be dealt with in early stages of vision processing.

Keywords:-Gaussian blur, Han filter, median filter, morphological operations, spatial filter, temporal filter, image histogram

I. INTRODUCTION

The Purpose of smoothing is to reduce noise and improve the visual quality of the image. A variety of algorithms i.e. *[linear]* [1] and *[nonlinear]*[2]-algorithms are used for filtering the images. Image filtering makes possible several useful tasks in image processing. A filter can be applied to reduce the amount of unwanted noise in a particular image as shown in fig. Another type of filter can be used to reverse the effects of blurring on a particular picture.*Nonlinear filters* have quite different behavior compared to *linear filters*. For *nonlinear filters,* the filter output or response of the filter does not obey the principles outlined earlier, particularly scaling and shift invariance. Moreover, a *nonlinear filter* can produce results that vary in a non-intuitive manner.

Defected image Real image
Fig 1- A Defected image and real image after applying filtering

This paper mainly contains the five sections which describes the different algorithms and techniques. Section *1* describes the simple introduction about image filtering . *Section II* elaboratesthe mean filter for filtering the images . Then *section III* contains the various algorithms for image smoothing. In *Section IV* we have describe the various techniques for filter the images .*Section V* contains the conclusion of this paper *i.e.* which algorithm is the best for removing the noise (filtering) from images.

II. WORKING EXAMPLE:-The mean filter

The simplest filter to implement is known as the [mean filter][3]. The mean filter performs average smoothing on an image .The name perfectly describes the function of this filter. Each pixel in I (image) is replaced with the mean of the pixels that surround it. Especially, noise is blended into the rest of the picture. A filter that performs average smoothing must use a kernel with all entries being non-negative. For example if a kernel A was used with m(size)=3:

$$A_{avg} = 1/3\ [1\ 1\ 1]$$

Let I be an image of size N, m an odd number smaller than N, and A the kernel of a linear filter, that is a mask of size m**.** Additionally,it is absolutely necessary for all the entries in the kernel to have a sum of one. If the sum is not equal to one ,then the kernel must be divided by the sum of the entries(hence the multiplication of the 1/3).If the requirement is not met, then the filtered image will become brighter than the original image, along with undergoing the specified filtering effect. This limitation on the mean filter fulfills the seconded portion of the image filtering goal A. This filter is effective at attenuating noise because averaging removes small variations. The effect is identical to that of averaging a set of data to help reduce the effect of outliers. In a two-dimensional mean filter, the effect of averaging m^2 noisy values around pixel divides the standard derivation of the noise by $\sqrt{m^2}$=m(size).

III. ALGORITHMS FOR IMAGE FILTERING

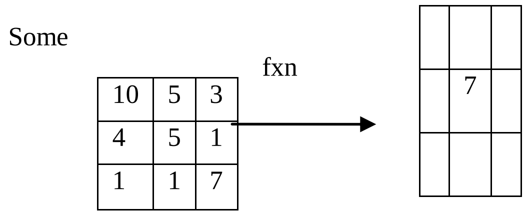
A.Linear Smoothing :-The most common, simplest and fastest kind of filtering is achieved by linear filters. The linear filter replaces each pixel with a linear combination of its neighbors and convolution kernel is used in prescription for the linear combination.[4]

Linear filtering of a signal can be expressed as the convolution .

$y(t)=\int_{-\infty}^{\infty}(h(r).x(t-r)dr)$

of the input signal x(n) with the impulse response h(n) of the given filter, i.e. the filter output arising from the input of an ideal Dirac impulse .Now from fig. it is clear that image filtering is done by applying function and when we apply linear filtering then each pixel is replaced by linear combination of its neighbor.

***Image filtering*:-**



Linear filtering:-

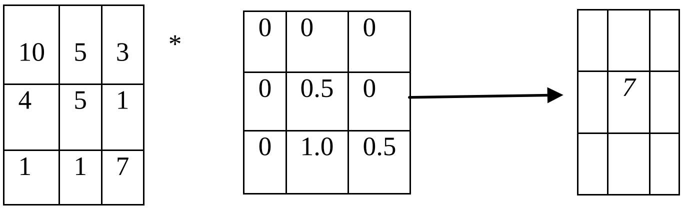


Fig-2-Evaluation of image filtering and linear filtering

A.1 Box blur

A box blur, also known as "moving average", is a simple linear filter with a square kernel and it contains all the kernel coefficients equal. It is the quickest blur algorithm, but it has a drawback *i.e.*it lacks smoothness of a Gaussian blur.

A box blur can be with a complexity independent of a filter radius. The algorithm is based on a fact that sum S of elements in the rectangular window can be decomposed into sums C of columns of this window: -

$$S[I,J] = \sum_{k=-r}^{n} C(I, j + k)$$

(column)with FET ,do the same with a zero-padded Gaussian kernel, then multiply complex spectra and do the inverse transform.

A.II Hann Window

Hann window is a smooth function defined as

$$H(t)=1+COS(t), -\pi \le t \le \pi$$

The algorithm that we propose in ID Hann smoothing is based on modulation of the input signal with a complex exponent .Let's consider a discrete filtering with a Hann kernel:

$$h(t) = \frac{1}{2r+1}\sum_{k=-r}^{r}(1 + \cos(k\pi/r) + 0.5)x[t + k]$$

This can be rewritten as sum of a box filter and a cosine modulated input signal. .Now we will solve the update formula for fast calculation of a cosine modulated real-valued signal.By calculating above equation we find out the solution as-:

$$0.5 \le \sigma \le 2.5$$

A relative accuracy of this approximation increases as filter radius σ increases, but even with small σ the 3.

A.III Gaussian Blur

[Gaussian blur][5] is considered a "perfect" blur for many applications, provided that kernel support is large enough to fit the essential part of the Gaussian. Gaussian filter on a square support is separable, i.e. In case of 2D filtering it can be decomposed into a series of 1D filtering for rows and columns. When the filter radius is relatively small (less than few dozen), the fastest way to calculate the filtering result is direct 1D convolution.First of all, it is considered that the result of convolution has a length N+M–1, where N is the signal size and M is a filter kernel size (equal to 2r+1), i.e. the output signal is longer than the input signal.

Secondly, calculating FFT of the complete image row is not optimal, since the complexity of FFT is O(N log N). The complexity of FFT (*fast Fourier transform*)can be reduced by breaking the kernel into sections with an approximate length M and performing overlap-add convolution section-wise. The FFT size should be selected so that circular convolution is not included. Usually optimal performance is achieved when FFT size F is selected as the smallest power of 2 larger than 2M, and signal section size is selected as F–M+1 for full utilization of FFT block. This reduces the overall complexity of 1D convolution to O(Norm).So, the per-pixel complexity of Gaussian blur becomes O(log r). However, the value of constant is quite large.So for many practical purposes Gaussian blur can be successfully implemented with simpler filters.

B. Nonlinear Smoothing

B.1 Median filtering

In signal processing, it is often desirable to be able to perform some kind of noisereduction 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 preprocessing step to improve the results of later processing (for example, edge on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges of the images while removing noise.

Median is a non-linear local filter whose output value is the middle element of a sorted array of pixel values from the filter window. Since median value is robust to outliers, the filter is used for reducing the impulse noise. Now we will describe median filtering with the help of example in which we will placed some values for pixels.

Example

To demonstrate, using a window size of three with one entry immediately preceding and following each entry, a median filter will be applied to the following simple 1D signal:

x = [2 80 6 3]

So, the median filtered output signal y will be:

y[1] = Median[2 2 80] = 2

y[2] = Median[2 80 6] = Median[2 6 80] = 6

y[3] = Median[80 6 3] = Median[3 6 80] = 6

y[4] = Median[6 3 3] = Median[3 3 6] = 3

i.e. y = [2 6 6 3].

In the above example, because there is no entry preceding the first value, the first value is repeated, with the last value, to handle the missing window entries at the boundaries of the signal, but there are other schemes that have different properties that might be preferred in particular circumstances.

Avoid processing the boundaries, with or without cropping the signal or image boundary afterwards, fetching entries from other places in the signal. With images for example, entries from the far horizontal or vertical boundary might be selected.

Some of the properties of median filters are-:

- Processes one color channel only.
- Takes the "not processing boundaries" approach”

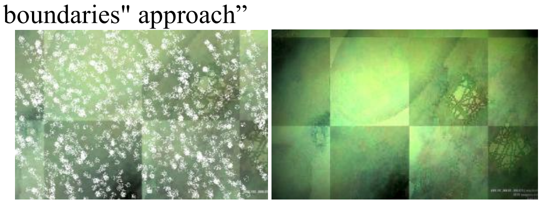


Fig:-3.Use of a median filter to improve an image severely corrupted by defective pixels

Since large computational time and effort is spent on calculating the median of any window. Because filter consider every entry in the signal and then median of that values is calculated. Some types of signal contain the whole number representation. In that case the images can be easily described by histograms and median can be easily calculated in that case. Let’s take an image to explain this concept by constructing the histogram of that image as shown in fig 4.which is very helpful in calculating the median of the pixels.

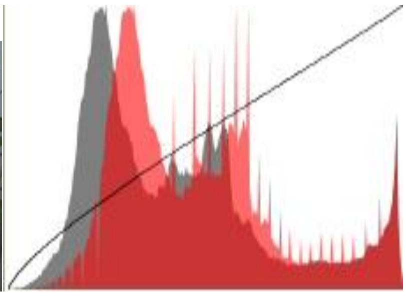


Fig:-4 Image of sunflower Histogram of sunflower image

Since image histogram is a type of histogram that acts as a graphical representation of thetonaldistribution in a digital image. Image histograms are present on many modern digital cameras. Photographers can use them as an aid to show the distribution of tones captured, and whether image detail has been lost to blown-out highlights or blacked-out shadows.[6]Image enhancement is one of the most important concepts in image processing. Its purpose is to improve the quality of low contrast images, i.e., to enlarge the intensity difference among objects and background. And histograms are very important in case of image enhancement and image processing.

The straightforward implementation of median filter requires O (r2logr) operations per pixel to sort the array of (2r+1)(2r+1) pixels in a window. However an optimization is possible when image data takes a limited range of discrete values, e.g. 8-bit pixel values. It is based on a fact that median value can be easily calculated from a histogram of pixel values in a window. For 8-bit pixel values such a histogram contains 256 bins and can be searched for a constant time (8 comparisons) independently of a filter radius. When a filter window shifts, thishistogram can be effectively updated. If the filter window shifts one pixel down, the pixels of upper window row are removed from the histogram (2r+1 operations), and pixels of a new lower window row are added to the histogram (2r+1 operations).

To optimize the histogram search, a previously calculated median value can be used as a starting point in a search for a new median value. A further optimization of median filtering is possible by maintaining several histograms as combining them in a certain way.

B.II Binary morphological operations

A basic morphological operation is dilation. When a structuring element is defined inside a square window with a radius r, the dilation operation sets to 1 all the pixels from which the structuring element overlaps at least one non-zero pixel of the source image. A straightforward implementation of dilation requires O(r2) operations per pixel to check all the points of structuring elements.

If we keep the number of non-zero pixels that are overlapped by a structuring element, an efficient update rule can be used for this number. When a structuring element window shifts one pixel to the right, some image pixels that can become overlapped are shifting in from the right border of a structuring element, and some image pixels can be shifting out of overlapping area through the left border of a structuring element. So, instead of counting a total number of overlapping pixels, we can increment the previous count by a number of pixels covered by the right border of the structuring element and decrement by the number of pixels that are lying to the left of the left border of a structuring element. The complexity of this optimized dilation is O(r).A similar optimization is possible for erosion operation. For erosion we will count the number of zero image pixels overlaid by a structuring element.

B.III Min/Max filters[8]

A max filter outputs a maximal pixel value from its rectangular window. A straightforward implementation requires O(r2) operations per pixel.

In case of small data bit depth, a histogram approach can be used. But when the bit depth is large, another approach based on a 1D running max filter appears more practical. A simple and fast algorithm called MAXLINE2 is using a circular buffer of delayed input elements. The[anchor points][9] to the current maximal value. When the window is shifted, a new element is added to the delay line and compares against anchor element. If the new element is smaller, the maximum stays at the anchor. Otherwise anchor moves to a new element. When the anchor shifts out of the delay line, the whole delay line is scanned for a new anchor.

This algorithm works very fast on IID (independent identically distributed) data, but has a worst-case complexity of O(r) for a monotonically decreasing data. An algorithm with a better worst-case complexity (although with a worse complexity on IID data) is also intr. It has a complexity of Oleg).This running max algorithm can be used for adding pixels to a 2D window of a 2D min/max filter with a worst-case complexity of O(log) operations per pixel.

B.IV Grayscale morphological operations:-

Grayscale morphology is simply a generalization from 1 bop (bits per pixel) images to images with multiple bits/pixel, where the Max and Min operations are used in place of the OR and operations, respectively, of binary morphology.

Grayscale morphological operations are based on min/max filters. When structuring element is rectangular, they can be optimized by using min/max filter.

III. VARIOUS TECHNIQUES FOR IMAGE FILTERING

The purpose of smoothing is to reduce noise and improve the visual quality of the image. Often, smoothing is referred to as filtering. There are two types of filters that have been found useful in nuclear medicine:-

A. Spatial filter

B. Temporal filter

Spatial filters are applied to both static and dynamic images, whereas temporal filters are applied only to dynamic images.The simplest smoothing technique is the nine-point smooth. The nine-point smooth will take a 3-x-3 square of pixels (total of nine) and determine the number of counts in each pixel. The counts per pixel are then averaged, and that value is assigned to the central pixel (Figure 5). This same operation can be repeated for the entire computer screen or restricted to a designated area. Similar operations can be performed with 5-x-5 or 7-x-7 squares.

5	7	3
4	2	5
6	2	2

3-x-3 square values

5+7+3+4+2+5+6+2+2=4(average value)

5	7	3
4	4	5
6	2	2

3-x-3 square values after smoothing
Fig 5- Simple Nine-Point Smooth Schematic

A Spatial filters:-A wide array of methods, as well as several dedicated 'spatial' econometric procedures for the statistical analysis of geo referenced data is available in the literature. These techniques are useful when analyzing regional unemployment data, as in our case study, and, particularly, when the final aim is to develop forecasting models for some regional scale. [10]

Among conventional spatial econometric methods, spatial auto regression is a powerful method commonly employed. Spatial autoregressive techniques take into account spatial effects by means of geographic weights matrices that provide measures of the spatial linkages (dependence) between values of geo referenced variables.

B. Temporal Filtering:- Temporal filtering allows reducing signals that are not correlated from frame to frame. It can very effectively reduce noise when combined with motion compensation, as motion compensation correlates the image content from frame to frame. This makes this processing suitable to improve the efficiency of subsequent encoders [11]. It is implemented using a recursive filter since it provides a better selectivity at lower costs.

The overall goal of temporal filtering is to increase the signal-to-noise ratio. Due to the relatively poor temporal resolution off MRI (*Functional magnetic resonance imaging*) , time series data contain little high-frequency noise. They do, however, often contain very slow frequency fluctuations that may be unrelated to the signal of interest. Slow changes in magnetic field strength may be responsible for part of the low-frequency signal observed in fMRI time series.

V. CONCLUSION

Many image filtering algorithms can be effectively implemented with a reduced number of operations per pixel. In this paper we have done the comparison between different image filtering algorithms. So, we conclude that median filtering approach is the best approach that can be easily implemented with the help of the imagehistograms. The median filter is demonstrably better than another algorithms at removing noise because it preserves edges for a given, fixed window size. [So, median filtering is very widely used in digital image processing.

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