

Image Edge Enhancement And Denoising Techniques For Computer Vision Applications

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Abstract— When dealing with images, denoising is an inevitable preprocessing part. The key in denoising also depends on the type of noises present in the image. There are different methods for denoising and the method suitable for computer vision application is chosen to be LOWESS and Savitzky-Golay smoothing techniques. Analyzing an image to extract the features of its contents require edge enhancement. Among the various types of techniques for enhancing the edges, Unsharp Masking is selected to suit the requirement for it gives good results. These methods can be used for the preprocessing phase of a vision processor or similar applications.

Keywords— Blurring, Denoising, Edge Enhancement, LOWESS Algorithm, Savitzky-Golay technique, Smoothing, Unsharp masking technique.

INTRODUCTION

Capturing visual information may be done using cameras of one's choice, but one will have to apply certain denoising techniques for cleaning the images obtained. Noises creep in due to reasons like camera misfocus, sensor noise, blur effect, etc. Camera misfocus may lead to blurred images and processing them is tedious. Sensor noises are unavoidable, whichever be the image sensors used. Some noises that are commonly found as referred in [5] are amplifier (Gaussian) noise, salt and pepper noise, shot noise, speckle noise, etc. Amplifier noise has a Gaussian distribution and hence it is known under that name also. Images with salt and pepper noise have dark spots (pixels) on brighter areas and white spots on darker areas. Such noises are generated due to analog to digital converters, bit transmission errors, etc. Shot noises are mostly found in lighter parts of an image due to variations in photons sensed at a given exposure level. Speckle noises are multiplicative and to eliminate all these noises, there are different methods available. Here the focus is on smoothing techniques.

In computer vision applications, the features of objects, primarily edges, are used to identify them. Objects in an image can be extracted efficiently when its edges are enhanced. There are different types of edge enhancement methods among which the Unsharp Masking technique is being discussed here. Unsharp masking is a type of sharpness enhancement, the other methods being high pass filters, high boost filtering etc. Contrast enhancement is another type which also has many applications.

THEORY

A. Edge Enhancement of color images

In colored images, enhancement of the colors is also important because edges can be colored also. Two methods to extract edges from multispectral satellite images were presented in [9]. A multispectral image was modeled as a vector field with the number of dimensions equal to the number of bands in the image. In this model, a pixel was defined as a vector formed by a number of elements equal to the number of bands. Two vector operators were applied to such vector field. In their first method, they extended the definition of the gradient. In this extension, the vector difference of the window central pixel with neighboring pixels was obtained. A multispectral image was then generated where each pixel represented the maximum change in spectral response in the image in any direction.. The other method, considered the generalization of the Laplacian by means of an h-dimensional Fourier transform. This image was named a multispectral Laplacian. The vector operators performed a simultaneous extraction of edge-content in the spectral bands of a multispectral image. These methods were parameter-free and they worked for a multispectral image of any number of bands.

Another method for edge enhancement in SAR (Synthetic aperture radars) images based on the exploitation of the information provided by the wavelet coefficients was proposed by Jaleel S et al, V. Bhavya, N.C. Anu Sree and P. Sajitha [10]. It managed the multi-scale data in a different way. It worked exclusively in the transform domain. They said that their proposed approach would tackle the robustness and the precision issues of edge enhancement and detection at the same time.

Al-Samaraie M et al and Al Saiyd N et al in the reference[11] proposed a method for enhancing and sharpening medical color digital images. They used the wavelet transforms and Haar transform followed by using the Sobel, the Laplacian operator to obtain the sharpened image. First, a medical image was decomposed with wavelet transform. Next, all high-frequency sub-images were decomposed with Haar transform and the noise in the frequency field was reduced by the soft-threshold method. Later the high-frequency coefficients were enhanced by different weight values in different sub-images. Then, the enhanced image was obtained through the inverse wavelet transform and inverse Haar transform. Lastly, the filters were applied to sharpen the image; the resulting image was then subtracted from the original image.

Another method for color image enhancement was proposed by S. Bettahar, A. B. Stambouli, P. Lambert and A. Benoit [12] as an extension of scalar diffusion-shock filter coupling model, where noisy and blurred images were denoised and sharpened. The proposed model was based on using single vectors of the gradient magnitude and the second derivatives as a technique to relate different color components of the image. This model could be viewed as a generalization of Bettahar-Stambouli filter to multi-valued images. Their experiments showed that their proposed algorithm was more efficient than the mentioned filter and some previous works on color image denoising and deblurring without creating false colors.

Starck J et al, Murtagh F et al, Candès E et al, and Donoho D et al [13] presented a new method for contrast enhancement based on the curvelet transform. They stress on curvelet transform because it represented edges better than wavelets, and therefore well-suited for multi-scale edge enhancement. Their findings were that curvelet based enhancement out-performs other enhancement methods on noisy images, but on noiseless or approximately noiseless images curvelet based enhancement was not remarkably better than wavelet based enhancement.

The Unsharp mask method is a sharpening operator which enhances the edges and other high frequency components in an image by subtracting a blurred version of an image from the original image[14]. The Unsharp filtering technique is mostly used in the photographic and printing industries for crispening the edges. First, a blurred version of the image is created. It is subtracted from the original one to obtain the mask. The mask is then added to the original image to get the enhanced image.

B. Denoising of Images

Noise in natural color photos has special characteristics that are different from those that have been added artificially. Wang Y et al and Zhou H et al [8] proposed a Multiscale Total Variational method (MTV) for denoising. The MTV method is a variational PDE method using wavelet bases. They found that the MTV method was well effective in denoising monochromatic images. Denoising methods for monochromatic images are numerous, which include neighborhood filters, frequency domain methods, variational PDE based methods and non-local methods. There are pros and cons for each method, but they vary with images. But in HUVIS Pro, the interest is to denoise color images as well.

Wavelet transform gives a superior performance in image denoising due to properties such as sparsity and multi-resolution structure. Thus the focus was shifted from the Spatial and Fourier domain to the Wavelet transform domain. Different types of noises would be amplifier (Gaussian) noise, salt and pepper noise, shot noise, speckle noise etc.

SUREShrink [15] uses a hybrid of the universal threshold and the SURE [Stein's Unbiased Risk Estimator] threshold and performs better than VISUShrink. Cross Validation [16] replaces wavelet coefficient with the weighted average of neighborhood coefficients to minimize generalized cross validation (GCV) function providing optimum threshold for every coefficient. The assumption that one can distinguish noise from the signal solely based on coefficient magnitudes is violated when noise levels are higher than signal magnitudes.

We can make it more adaptive by choosing different threshold values in a sub band. Basics of denoising involve operating around choosing the appropriate thresholds. S.Y.Pattar [6], proposed an approach 'modified stochastic method' where band corresponding to detail coefficients were also decomposed to utilize the information present in the details part. The decompositions were followed by determination of the threshold limit in each sub band. This made the threshold limit to be chosen adaptively and causes better denoising. His results had shown that there has been considerable improvement in terms of Peak signal to noise ratio (PSNR) in

comparison with other techniques. The Modified stochastic model uses correlation properties of signal in each sub-band and thus makes proper determination of an edge and noise in the image. Thus, this results in edge preservation in the image and retention of the good visual quality of the images. He had considered orthogonal wavelet for analyzing the characteristics of the signal. If instead, we could use non orthogonal or semi orthogonal wavelets for analyzing, the coefficients obtained would be more correlated and could give still better denoising techniques.

Smoothing of image is a way of denoising it. It is use to draw a smooth curve through an image or through an object's edges. There are different types of smoothing techniques.

$Z = \text{smooth}(Y, \text{SPAN}, \text{METHOD})$ smooths data Y with specified METHOD . The available methods are:

'moving' - Moving average (default)

'lowess' - Lowess (linear fit)

'loess' - Loess (quadratic fit)

'sgolay' - Savitzky-Golay

'rloess' - Robust Lowess (linear fit)

'rloess' - Robust Loess (quadratic fit)

$Z = \text{smooth}(Y, \text{METHOD})$ uses the default SPAN 5.

$Z = \text{smooth}(Y, \text{SPAN}, \text{'sgolay'}, \text{DEGREE})$ and

$Z = \text{smooth}(Y, \text{'sgolay'}, \text{DEGREE})$.

IMAGE ENHANCEMENT TECHNIQUE

A. Unsharp Masking Technique

There is a procedure for performing the Unsharp masking method as shown in Figure 1.

In Unsharp masking technique referred in [1], prior to enhancing , a mask is to be created for which the image has to be blurred. A blur kernel is used for the same according to the following equation.

$$\text{kernel} = \frac{1}{2\pi s^2} e^{-\frac{(X-m)^2 + (Y-m)^2}{2s^2}}$$

The '*' denotes convolution of the original image and the blur kernel. Once the image is blurred, it is subtracted from the original image to get the mask. The mask is added to the original image, with a gain if needed, to obtain the enhanced image.

The basic equation of Unsharp masking technique is

$$v = y + \gamma(x - y)$$

where 'x' is the input image, 'y' is the result of linear low pass filter and gain ' γ ' > 0 is a real scaling factor.

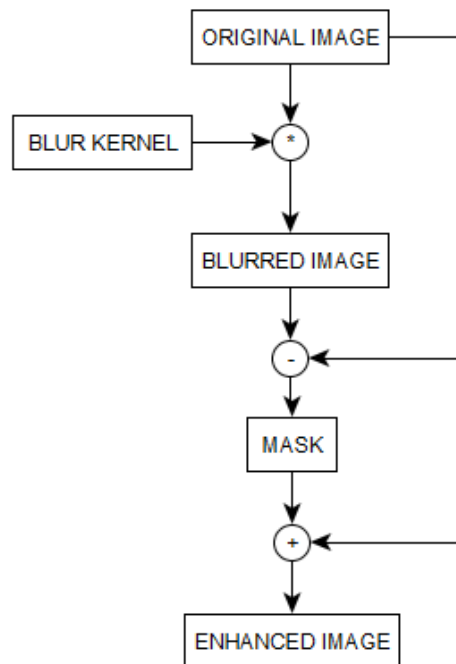


Figure 1. Flowchart of Unsharp masking method

IMAGE DENOISING TECHNIQUE

As mentioned in [5], denoising can be done either by transform domain filtering or spatial domain filtering. Spatial filtering includes non-linear filters like median and weighted median filters along with linear filters like mean and Weiner filters. The transform domain filtering includes spatial frequency filters and wavelet domain ones having adaptive and non adaptive filters.

Denoising of color images requires more care than gray scale ones. It is usually advised to use the YCrCb format rather than RGB for denoising. The reason for this as explained in [8] is that the former is linear. Reference [8] also tries to create a new color space for superior performance. Here this paper describes the method using the RGB format itself to denoise the image. Smoothing is a kind of denoising that can be performed which is being selected in this context. Usually, the cameras provide outputs in RGB format which can directly be used for denoising without manipulations.

A. Smoothing Methods

From the matlab Toolbox, different smoothing algorithms for image processing are available. Two of the algorithms are being used here, namely LOWESS and Savitzky-Golay algorithms.

LOWESS Algorithm

Many expanded forms for LOWESS is found, like 'locally weighted least squares', 'locally weighted regression' etc. it carries out robust locally weighted time series and scatter plot smoothing for equispaced and non-equispaced data. This is addressed as local because the process is carried out using the neighboring set of data points defined within the span. This is also weighted because a weight function is defined for those data points.

Savitzky-Golay Algorithm

This is a digital filter used on data points to smoothen them to increase the signal to noise ratio without distorting the signal much. When the data points are equally spaced an [analytical solution](#) to the least-squares equations can be found, in the form of a single set of 'convolution coefficients' that can be applied to all data sub-sets, to give estimates of the smoothened signal, (or derivatives of the smoothened signal) at the central point of each sub-set. The method was popularized by [Abraham Savitzky](#) and [Marcel J. E. Golay](#) who published tables of the convolution coefficients for various polynomials and sub-set sizes in 1964. The tables had been corrected later and has been extended for the treatment of 2- and 3-dimensional data.

SIMULATION

The test image Figure 2. contains four different basic shapes which are first edge enhanced and then smoothed to get good results. Normally, denoising techniques are performed in the first phase, but here denoising after edge enhancement using the mentioned methods gave good results.

Enhanced image is good enough to extract the features of objects. If a *jpeg* compression occurs, some of the data would be lost. The smoothing algorithms help in rectifying such noises.

The simulation is done in Matlab, an image processing tool, where the images can be read and processed in spatial or frequency domains.

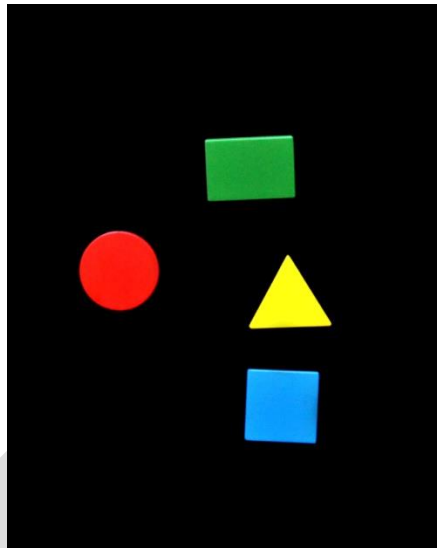


Figure 2. Test Image

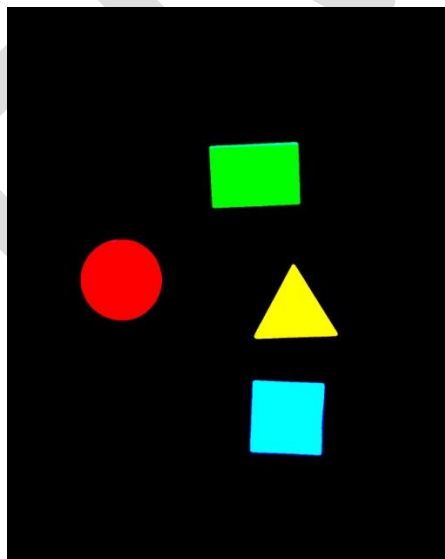


Figure 3. Enhanced Image

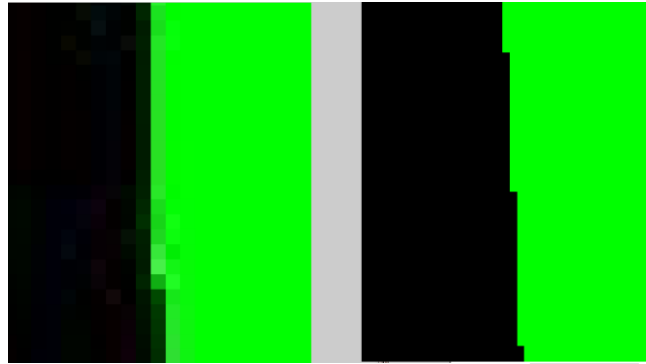


Figure 4. Smoothened Image (closer glance)

ACKNOWLEDGMENT

I am grateful to God Almighty for showering His blessings on me throughout my life. I am thankful to my college, Toc H Institute of Science and Technology, for providing me the platform to make my studies. I thank my parents, professors and friends for their support.

CONCLUSION

Denoising methods are inevitable when one deals with images taken from an image sensor. For any computer vision application, the mentioned method is useful. Edge enhancement is done for easy feature extraction of objects of interests. These methods are studied for the purpose of an application which emulates human vision.

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