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Sharpness Enhancement and Denoising of Image Using L1-Norm Minimization Technique in Adaptive Bilateral Filter

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Abstract: ***In Image processing, Image restoration technique plays a vital role. Removing mixed noise from images is a challenging problem. This paper presents a novel technique of Image sharpening and Denoising using the L1-norm minimization technique in Adaptive Bilateral Filtering. The objective of this paper is to explore the advantage of new technique over the existing ones. This employs comparison of results obtained using both L1 and L2-norm minimization techniques. In this paper, we consider Least Absolute Deviation (L1) method for image restoration in ABF. This method finds application in many areas due to its robustness as compared to Least Squares method (L2).***

Keywords: L1 and L2 norms, LAD, Least squares, ABF, Image Restoration.

1. Introduction

The images are becoming very important tool nowadays in our daily life applications such as satellite imaging, radio diagnosis in medical field. Digital images also have its importance in areas of research and technology such as geographical information systems and astronomy. Data sets collected are usually affected with some noise. Noise is any undesired information that contaminates an image. Noise may render the user with the original information that can be retrieved from the image data. Thus denoising is an important aspect of image restoration before image analysis. The sources of noise can be any among imperfect instrument, unskilled photographer, unpleasant weather or improper light and transmission errors etc.

It is necessary to apply an efficient denoising technique to compensate for such data corruption. Image denoising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the image. Edge Enhancement is an important pre-processing step for any image processing application.

1.1 L1-Norm

What is a norm?
Mathematically a norm is a total size or length of all vectors in a vector space or matrices. For simplicity, we can say that the higher the norm is, the bigger the (value in) matrix or vector is. Norm may come in many forms and many names, including these popular names: Euclidean distance, Mean-squared Error, etc.

A n-th root of a summation of all elements to the n-th power is what we call a norm. L1 norm is quite common among the norm family. It has many name and many forms among various fields, namely *Manhattan norm* is its nickname. If the L1-norm is computed for a difference between two vectors or matrices, so it is called Least Absolute Difference (LAD).

L1-norm is also known as least absolute errors (LAE). It is basically minimizing the sum of the absolute differences **(S)** between the target value ($\mathbf{Y_i}$) and the estimated values ($\mathbf{f(x_i)}$):

$$S = \sum_{i=1}^{n} |y_i - f(x_i)|. \quad (1)$$

1.2 L2-Norm

L2-norm is also known as least squares. It is basically minimizing the sum of the square of the differences **(S)** between the target value ($\mathbf{Y_i}$) and the estimated values $\mathbf{f(x_i)}$:

$$S = \sum_{i=1}^{n} (y_i - f(x_i))^2 \quad (2)$$

L2 norm is well known as a Euclidean norm, which is used as a standard quantity for measuring a vector difference. It's most well known application in the signal processing field is the *Mean-Squared Error (MSE)* measurement, which is used to compute a similarity, a quality, or a correlation between two signals. However, even though the solution of Least Square method is easy to compute, it's not necessary be the best solution. Because of the smooth nature of l_2-norm itself, it is hard to find a single, best solution for the problem.

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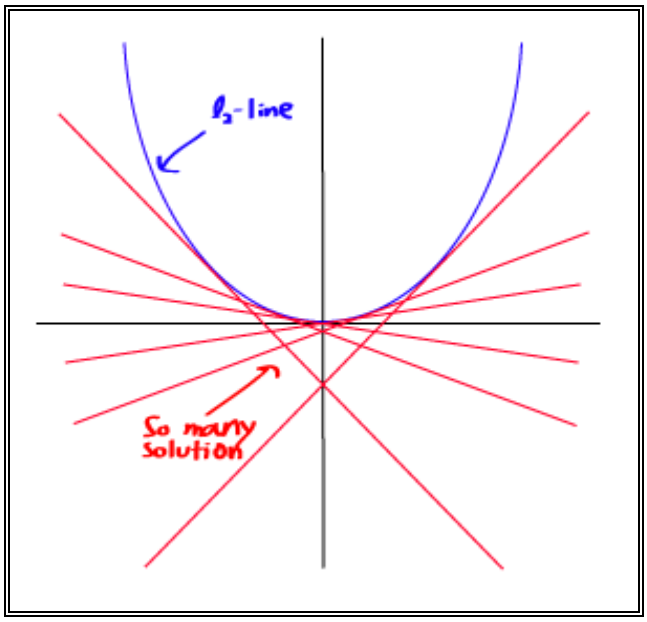


Figure 1: Solution for l2-norm minimization

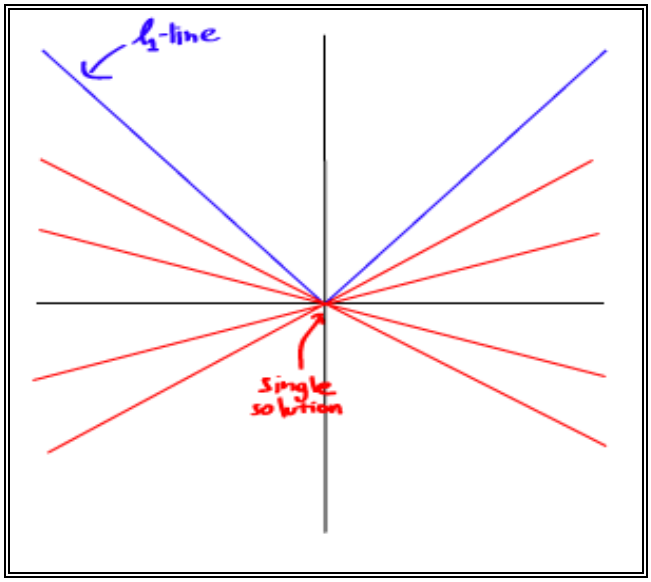


Figure 2: Solution for l2-norm minimization

In contrary, the l1-optimisation can provide much better result than this solution. Because the nature of l1-norm is not smooth as in the l2-norm case, the solution of this problem is much better and more unique than the l2-optimisation.

2. Comparison Between L1 and L2 Norms

Least Square Regression (L2)	*Least Absolute Deviation (L1)*
Stable Solution	Not Stable
Always One Solution	Many Solutions
Not Robust	Very Robust
No Feature Selection	Built-In Feature Selection
Non-Sparse Outputs	Sparse Outputs
Computationally Efficient	Computationally Inefficient
Have Analytical Solutions	Non-Analytical Solutions

Figure 3: Difference between l1-norm and l2-norm

The method of least absolute deviations finds applications in many areas, due to its robustness compared to the least squares method. The instability property of the method of least absolute deviations means that, for a small horizontal adjustment of a datum, the regression line may jump a large amount. In contrast, the least squares solutions is stable in that, for any small adjustment of a data point.

In this picture below, the green line (L2-norm) is the unique shortest path, while the red, blue, yellow (L1-norm) are all same length (=12) for the same route .This defines the uniqueness of L2-norm. It can be more clearly understood by given figure below:

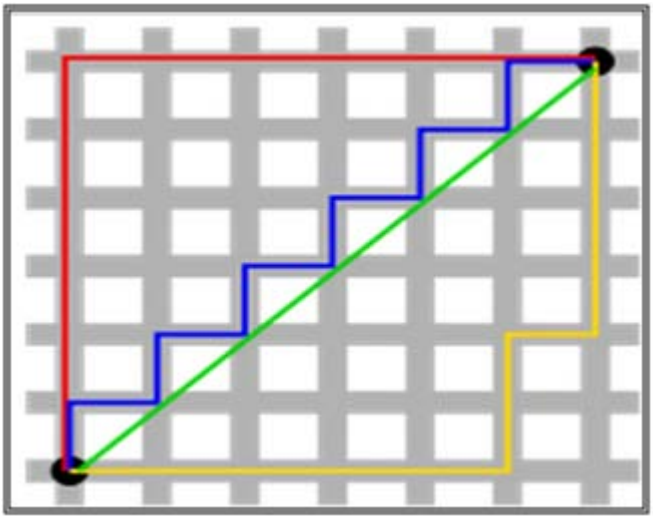


Figure 4: Solution Uniqueness

Built-in feature selection is frequently mentioned as a useful property of the L1-norm, which the L2-norm does not. In case of computational efficiency, L1-norm does not have an analytical solution, but L2-norm has which allows the L2-norm solutions to be calculated computationally efficiently. However, L1-norm solutions do have the sparsity properties which allow it to be used along with sparse algorithms, which make the calculation more computationally efficient.

3. Problem Formulation

The problem statement is based on the evaluation of the time taken by the algorithm to produce a clear restored image from the noisy version of the same image. Here, the image is contaminated with Additive White Gaussian noise. The problem statement solution is calculated with the help of various algorithms which help us to calculate the parameters of noisy images, Mean Square Error and PSNR estimation between the restored images obtained by using same algorithm once with L2-norm and simultaneously with L1-norm.

Image denoising is a filed which has been into action for the last couple of decades to improve the image quality. A lot of research work has already been done into the same contrast. Our basic problem is to remove the noise from a noisy image using the Adaptive Bilateral filter. We also need to compare the results of the same filters when they are used with the different error minimization algorithms (L1 and L2-norm minimization) methods.

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4. Experimental Results

The adaptive bilateral filter which is developed in the same framework as that of a bilateral filter is an enhanced version of Bilateral Filter. It is clear from the observation that various experiments can be done to improve the quality of a digital image to retrieve its original form. In this paper we have experimented with the minimization technique used in the earlier methods to reduce the errors. Previous techniques and researches used the L2-Norm minimization technique to minimize the errors whereas; in this paper L1-Norm minimization is used for error reduction.

Most of the results are computed using the image shown in Fig. 5. The original image thus taken is subjected to white Gaussian noise in the pre-processing block. The output of this block is a noisy or corrupted image which is shown in Fig. 6. An Adaptive Bilateral Filter is used to enhance the sharpness of input image and remove the unwanted noise from it. The results of filtering by Adaptive bilateral filter using L1-norm minimization technique are shown in Fig.7. High quality, high resolution images are used for the training set .One image was left out of the training set to serve as a test image. The content of training image covers a variety of scenes. To generate the degraded images, we have added additive white Gaussian noise to the test image.

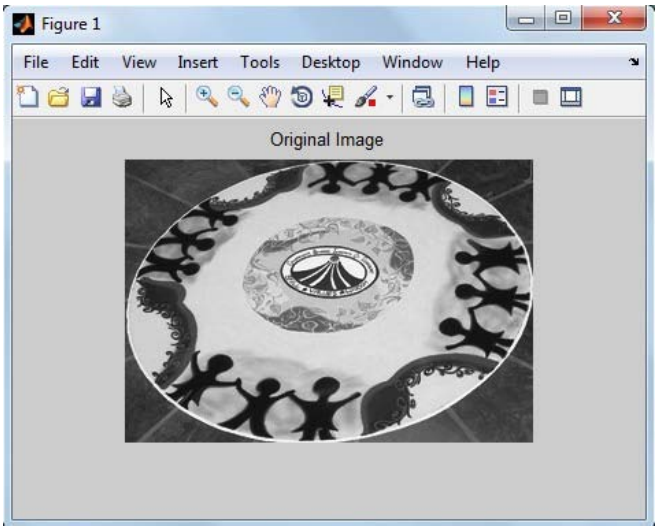


Figure 5: Original Image

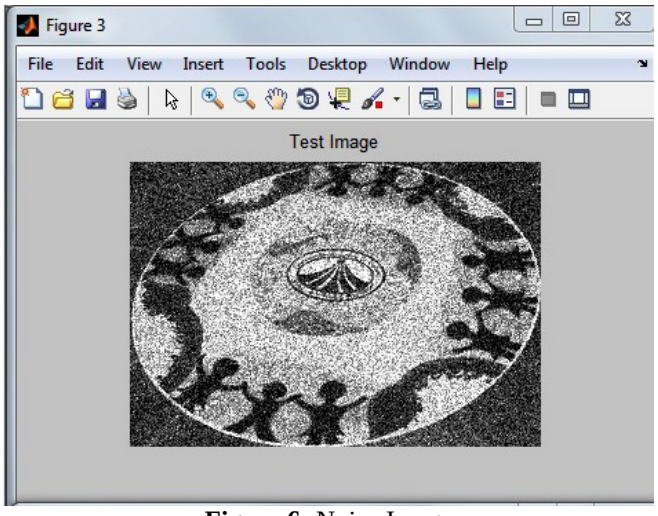


Figure 6: Noisy Image

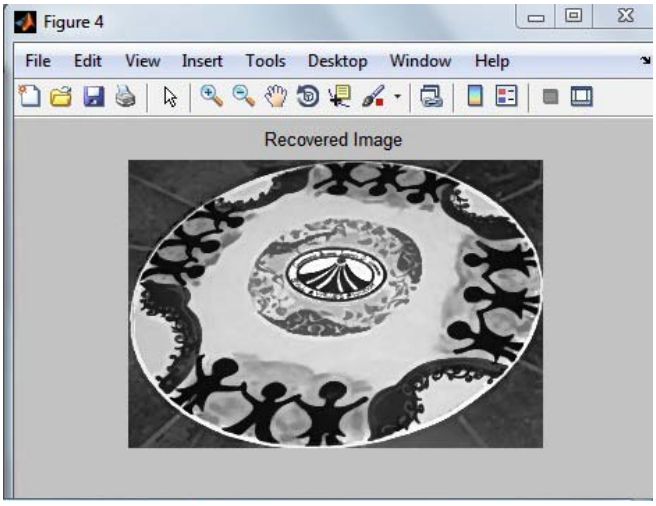


Figure 7: Recovered Image

5. Conclusion

In conclusion, efficient algorithm has been proposed to obtain high quality digital camera images using a Adaptive bilateral filter using L1-norm for error minimization. Unlike earlier technique i.e. L2-norm minimization, it produces much better visual quality images with a comparable high PSNR and low MSE values.

Thus, it proves to be an efficient algorithm for image denoising and sharpening. As there is no computation of squares in this method, it has a very high speed of producing recovered images from a noisy version of the same.

Hence, experimental results show that there are many advantages of LAD method over Least squares method.

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