

# Edge- Preserving Smoothing of Images using Guided Filter

Vrushali Patil

P.G. Student [VLSI & Embedded Systems],  
Department of E & TC, D. Y. Patil College of  
Engineering,  
Akurdi, Pune

P. Malathi, Ph.D

Professor,  
Department of E & TC,  
D. Y. Patil College of Engineering,  
Akurdi, Pune

## ABSTRACT

Filtering is widely used in image and video processing for various applications among which Edge- Preserving is the most popular one. Edge-preserving image smoothing has recently emerged as a valuable tool for a variety of applications such as denoising, tone mapping, non-photorealistic rendering in computer graphics and image processing. This can be achieved by a local filtering method such as bilateral filter [1]. However, this method has to face the problem of trade-off between edge-preservation abilities and smoothing abilities [2] and tends to result in staircase effect which is not acceptable for some applications. Hence, in this paper the guided filter is proposed which filters the output depending upon the information provided by the guidance image.

## Keywords

Edge-preserving filtering, bilateral filter, guided filter, guidance image

## 1. INTRODUCTION

Filtering is an image processing technique widely adopted in computer graphics, computer vision, computational photography, etc. It transforms the pixel intensity value to reveal certain image characteristics. More specifically, filtering can be applied in many applications such as noise reduction, colorization, edge preservation, detail enhancement, texture editing, haze/rain removal, etc. The most popular of this is the edge-preserving smoothing. Edge preserving smoothing refers to the image processing technique that results in smoothing of textures, while retaining the sharp edges. Since many natural images are described as a collection of gray value and oriented texture domains, a scale and orientation adaptive smoothing scheme provides a powerful noise reduction method. Edges between domains are the important features for the interpretation of images. However, smoothing operators tends to blur the edges or borders between the domains. Hence, such a filter is required to be used that not only reduce the noise but also does not degrade the edges, i.e. an edge preserving filter.

Linear translation invariant (LTI) filters such as Mean filters, Gaussian filters, Laplacian filters, all with explicit kernels have been widely used in image restoration, blurring/sharpening, edge detection, feature extraction, etc. LTI filtering also includes the method of solving Poisson's equation such as in HDR compression, image matting and image stitching, wherein the filtering kernels are implicitly defined by the inverse of a homogenous Laplacian matrix. The kernels included in LTI filters are spatially invariant and does not depend on the image content. But generally, it is

desirable to incorporate additional information from a given guidance image while filtering.

One way to achieve this purpose is to optimize a quadratic function which enforces some constraints on the unknown output with the help of guidance image, where the guidance image may be the filter's input itself or another image. Thus, a large sparse matrix encoded with the information involved in the guidance image is solved. Although this approach yields the state of art quality, it results in a long computational time. Another method is to explicitly build the guidance image into the filter kernels. Bilateral filter is the most popular one of such filters.

In this paper we have introduced a novel explicit image filter called Guided filter that overcome the gradient reversal artifacts introduced while using bilateral filter.

## 2. LITERATURE OF RELATED WORK

We review edge-preserving filtering techniques in this section categorized as explicit/implicit weighted average filters and non-average filters.

### 2.1 Explicit Weighted- Average Filters

The bilateral filter is perhaps the simplest and most intuitive one among explicit weighted-average filters. In [1], the concept of bilateral filtering for edge preserving smoothing was introduced. It was mentioned that a common technique for preserving edges during smoothing is to compute the median in the filter's support rather than computing the mean. Although this filter is effective in many cases such as noise removal and extraction of detail at a fine spatial scale, it has also been noticed that it may have artifacts in detail decomposition [2] and high dynamic range (HDR) compression [3]. Artifacts results from the pixels around the edge that have an unstable Gaussian Weighted Sum. Hence, the results may exhibit unwanted profiles around the edges. Fast implementation of bilateral filter also has been a challenging problem. The bilateral filter later generalized to joint bilateral filter [4], wherein the weights are computed from another guidance image rather than the filter input, is favored specifically when the image that is to be filtered is not reliable to provide the information about the edges. The reason behind it is that when a pixel on an edge has few similar pixels around it, the Gaussian weighted average becomes stable. For real time implementation [5], a bilateral filter involves histogram based approximation due to its computation efficiency and memory concern.

### 2.2 Implicit Weighted Average Filters

A series of approaches optimize a quadratic cost function and solve a linear system, which is equivalent to implicitly filtering an image by an inverse matrix. In image segmentation [6] and colorization [7], the affinities of this

matrix are Gaussian functions of the color similarities. The weighted least squares filter in [2] adjusts the matrix affinities according to the image gradients and produces halo-free edge-preserving smoothing.

Although this optimization based approaches often generate high quality results, solving the linear system is time consuming. Direct solvers like Gaussian Elimination are not practical due to the memory-demanding “filled in” problem. The implicit weighted-average filters take at least a few seconds to process a one megapixel image either by preconditioning or by multi-grid [2].

### 2.3 Non-average Filters

Edge-preserving filtering can also be achieved by non-average filters. The median filter is an edge-aware operator and also a special case of local histogram filters [8], wherein histogram filters have  $O(N)$  time implementations in a way as the bilateral grid. The Total-Variation (TV) filters [9] optimize an L1-regularized cost function, and are shown equivalent to iterative median filtering [10]. The L1 cost function can also be optimized via half-quadratic split [11], alternating between a quadratic model and soft shrinkage. But it has been noticed that non-average filters are computationally expensive.

## 3. PROPOSED GUIDED FILTER

In order to overcome the artifacts[2][3] introduced by bilateral filter, a new edge preserving performance known as Guided image filter is proposed that will filter the output depending upon the information of the guidance image. Guided image filtering is one of the spatial domain enhancement technique in which the filtering output is locally a linear transform of the guidance image. Guided filter has good edge-preserving smoothing properties and does not suffer from the gradient reversal artifacts that are seen when using bilateral filter. It can perform better at the pixels near the edge when compared to bilateral filter. The guided filter is also a more generic concept beyond smoothing. By using the guidance image, it makes the filtering output more structured and less smoothed than the input. It can transfer the structures of the guidance image to the filtering output, enabling new filtering applications such as dehazing and guided feathering. Also, guided filter adopts the fast and non-approximation characteristics of linear time algorithm and provides an ideal option for real time applications in case of HD filtering. Hence, it is considered to be one of the fastest edge preserving filters.

Guided filter generally has an  $O(N)$  time (in the number of pixels  $N$ ) exact algorithm for both gray scale and color images, regardless of the kernel size and the range of intensity.  $O(N)$  time represents that the time complexity is independent of the window radius( $r$ ) and hence arbitrary kernel sizes can be used in the applications.

Here, the main idea and equations of a guided filter is reviewed. The key assumption of the guided filter defines a local linear model between the guidance image  $I$  and the filtered output image  $q$ , taking  $p$  as an input image as shown in fig.1.

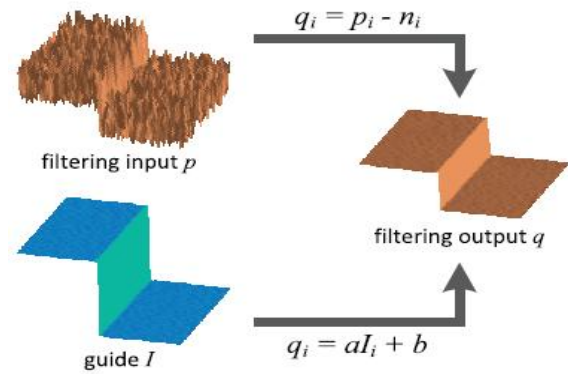


Fig. 1. Illustration of guided filtering process

It is assumed that  $q$  is a linear transform of  $I$  in a window  $w_k$ , that is centered at pixel  $k$ .

$$q_i = a_k I_k + b_k \forall i \in w_k \quad (1)$$

where,  $a_k$  and  $b_k$  are considered to be linear coefficients that are constant in  $w_k$ . The relation of pixel  $i$  and the related windows ( $w_i$  and  $w_k$ ) is shown in fig.1. This local linear model ensures that  $q$  has edge only if  $I$  has edge.

In order to determine the linear coefficients ( $a_k, b_k$ ), we need constraints from the filtering input  $p$ . We model the output  $q$  as the input  $p$  subtracting some unwanted components  $n$  like noise/textures:

$$q_i = p_i - n_i \quad (2)$$

Fig.2 shows the flow of edge preserving smoothing for an image using guided filter.

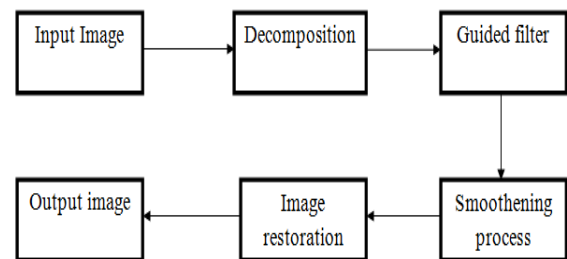


Fig. 2. Block diagram of the proposed work

The input image that is in the form of either jpeg or bmp is required to be converted into gray level. Further, noise is added to the image and then is converted into gray level image. Later decomposition is done, wherein the 2D input image is converted into 1D image. Filtering is performed using guided filter so that there will be no loss of information at the edges of the image. Then retrieving back the filtered input image from 2D to 1D, the filtered output image gets displayed.

## 4. CONCLUSION

Differently from the recent trend accelerating towards the bilateral filter, a new filter is proposed that exhibits the property of edge preserving smoothing that can be computed efficiently. Guided filter performs very well in terms of both quality and efficiency in a great variety of applications such as noise reduction, haze removal, image matting/ feathering, detail smoothing/enhancement, HDR compression and joint up-sampling. This filter has great

potential in computer vision and computer graphics in order to suppress and extract information from images.

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