Guided Filter Technique: Various Aspects In Image Processing

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Abstract—The guided image filter is based on a local linear model. The guided filter delivers the filtering output by considering a reference image. The reference image is said as the guidance image which can be the input image itself or another different image. The guided filter has better edge preserving smoothing and gradient preserving property. The guided filter is effectual in a variety of computer vision and computer graphics applications.

Keywords-*Edge preserving, Guided filter, Guidance image.*

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I. Introduction

Image processing involves many operations such as image enhancement, segmentation, image restoration. To perform these operations, filtering is the most fundamental and important process. A filtering function applied to the values of the input image in a predefined neighbourhood of the given location gives the filtered image in the same location. The linear translation invariant (LTI) filters, for example the Mean filter, Laplacian filter, Sobel filter, are used mostly for blurring, sharpening, noise removal, image enhancement, etc. The LTI filtering methods are applied in the spatial domain. In the spatial domain nonlinear spatial filters such as median filter, are also proved to be efficient. Considering the content of reference image which might be useful in some cases, the filtering techniques are proposed such as anisotropic diffusion, bilateral filter. But anisotropic diffusion is relatively slow. Also bilateral filter shows unwanted gradient reversal artifacts. For the next step of improvement, guided filter can be considered which also uses the content of the guidance image. The guided filter gives the output which is a local linear transformation of the guidance image. Depending upon the operation requirement, the guidance image can be same as the input image or different. In the guided filter has better gradient preserving property than bilateral filter. As the guided filter is local linear function of the guidance image, structure transference from the guidance image to the filtering output is also allowed. With these features, the guided filter stands the novel and efficient filtering operation.

II. Related Work

Edge preserving property is the most appreciated feature of filtering process. Traditional filters like average filter provides the smoothing including edges of the images too. Some edge preserving filters from the literature review are given as follows:

A. *Anisotropic Diffusion*

Anisotropic diffusion is very notable idea for edge aware image processing. The partial differential equations are the basic idea for anisotropic diffusion. The speed of the process is slow. If the intensity of each pixel is assumed to be heat and is propagated over time to its neighbours. Some improvements have been proposed to minimize operation time which in turn affects the accuracy.

B. *Median Filter*

The median filter is another popular edge aware filter, which can be considered as a special case of local histogram filters. The median is the statistical concept which means the center value of the provided list. The pixel under consideration is replaced with the median magnitude. It also shows property of noise reduction, while preserving edges more effectively as compared to a linear smoothing filter. Rank order and morphological processing are proposed variations for the basic median concept. But its practical use has been limited to small filter sizes due to its basic slowness.

C. *Bilateral Filter*

The bilateral filter is another noniterative strong approach to preserve edges in images. It produces filter output at the considered pixel as an average of neighbouring pixels. But the bilateral filter has disadvantage of gradient reversal artifact. For a pixel on an edge which has few similar pixels in the neighbourhood, the weighted average becomes unstable. The result is that the smoothed output is not consistent with the input at the edges. So detail enhancement like operations which requires the consistency of input signal and output signal has to be performed with better gradient preserving filter.

III. Conceptual Definition Of Guided Image Filter

Let us assume, I be a guidance image, p be an input image, and q be an output image to define guided filter.

The guided filter is modeled as a local linear model between the guidance I and the filtering output q. For any pixel I, the linear transform q of I in a windowω_k centred at the pixel k:

$$q_i = a_k I_i + b_k, \forall_i \in \omega_k \quad \ldots\ldots\ldots\ldots\ldots..(1)$$

where, (a_k, b_k) are assumed to be constant in ω_k.

To find linear coefficients, the cost function in window ω_k is defined as

$$E(a_k, b_k) = \sum_{i \in \omega_k} \left((a_k I_i + b_k - p_i)^2 + \varepsilon {a_k}^2 \right)$$

.... (2)

where, ε is a regularization parameter penalizing largea_k.

The term $\varepsilon {a_k}^2$is used to prevent a_k from being too large. $\varepsilon$is the blur degree to control the accuracy of edge detection. If the image I has no edges, the output will be an averaged result of input inω_k. If the edge is present in I which represent the structure of the guidance image, the edge is transferred to the output image.

The cost function can be seen as a linear regression model & its solution can be given by,

$$a_k = \frac{\frac{1}{|\omega|}\sum_{i \in \omega_k} I_i p_i - \mu_k \bar{p}_k}{\sigma_k^2 + \varepsilon} \ldots\ldots.... \quad ....(3)$$

$$b_k = \bar{p}_k - a_k \mu_k \ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots \quad (4)$$

where, μ_k and σ_k^2 are the mean and variance of I in ω_k,

$|\omega|$is the number of pixels in ω_k ,

$\bar{p}_k = \frac{1}{|\omega|}\sum_{i \in \omega_k} p_i$is the mean of p in ω_k.

Using linear coefficients (a_k, b_k) , the filtering output can be computed as

$$q_i = a_k I_i + b_k, \forall_i \in \omega_k \ldots\ldots\ldots\ldots..(5)$$

But, the values for q_i will be different when calculated for various windows. So, the solution is to find the average value of q_i. For all possible windows in the image, (a_k, b_k) values will be calculated and then the filtered output can be given as

$$q_i = \frac{1}{|\omega|} \sum_{k|i \in \omega_k} (a_k I_i + b_k) \ldots\ldots\ldots\ldots..(6)$$

Also, considering $\sum_{k|i \in \omega_k} a_k = \sum_{k \in \omega_i} a_k$ due to symmetry of the window, above equation can be written as

$$q_i = \bar{a}_i I_i + \bar{b}_i \ldots\ldots.\ldots\ldots (7)$$

where, $\bar{a}_i$and $\bar{b}_i$ are the average of coefficients for all windows overlapping i.

The guided filter also can be applied to colour images. In case input image is coloured, the filter should be applied to each channel separately.

IV. Guided Filter Algorithm

1. Firstly read the guidance image and the input image.
2. Enter the values of r and ε where r is the local window radius and ε is the blur degree of the filter.
3. Calculate the values: Mean of I, Variance of I, Mean of P, Average cross product of I and P.
4. Compute the value of linear coefficients.
   a = (cross_IP – mean_I.*mean_P)./ (var_ I+ ε)
   b = mean_ P - a. * mean _I
5. Compute the mean of a and b
6. Obtain the filtered output image Q using mean of a and b,
   Q = mean_ a. * I + mean _b

V. Aspects In Image Processing

Some aspects of guided filtering in image processing can be given as follows:

A. *Edge Preservation*

In image processing, images are often decomposed into a smooth base layer and one or more detail layers. The base layer describes intensity variations of image which is obtained by applying the filter on image. The difference between the original image and the base layer gives the detail layer. According to requirement of application, the layers may be processed with various approaches to get desired result. The base layer output is the blurred input image. The degree of blurring should be properly adjusted to avoid artificial edges in the final output image while further processing image. The edge preserving filter which prevents smoothening across the edges is best suited for these cases of image processing. Here guided image filter may be used, which is an excellent edge-preserving filter. The input image and the guidance image should be same. Also, the derived base layer using guided filter is consistent with the input image, which also represents gradient preserving property. This property avoids unwanted matching discrepancy between the base layer and detail layers. Edge preserving decompositions can be used in various image processing such as detail enhancement, HDR compression, details fusion, etc. For example, in image enhancement operation the base layer and the detail layer are processed in various ways and recombined. The quality of images for human viewing is improved by enhancement process.

B. *Image Denoising*

In image denoising techniques, image filters are applied to images to remove the different types of noise. The noise might incorporate with image either during capturing scene or transmission. Considering the denoising process with guided filter, N is the noisy image as input, while I is reference image as guidance. Basically, noise is nothing but high frequency details contained in the image which do not contain any relevant information. The processing in sync with lower frequency guidance image will stabilize the overall output frequency content, thus achieving the noise removal. Also, this process retains the structure of the guidance image and provides edge preserving smoothing. As the guidance image is usually free of noise, so is the filtered result. This aspect can be used where a reference image is made available free of noise.

C. Structure Transference

From the definition of the guided filter, it can be seen that the output and the guidance image are related to each other with linear equation. So it is obvious that, if the edge is present in the guidance image, then it will be transferred to the output image. This property can be used in applications like matting, feathering, etc. Image matting is nothing but to distinguish the foreground from background which requires exact mask. The mask can be obtained with the help of segmentation methods, which is later processed by using the guided filter to get accurate outline. In this case, the input image will be the mask and the guidance image is required to be the original image.

For obtaining desired results in a particular aspect, the guided filter parameter values have to be set. Also, the input image and the guidance image selection has to be made, same or different.

VI. IMPLEMENTATION OF GUIDED FILTER

The guided filter results for few ε parameter values from Matlab implementation are shown in below given figure. The guidance image I is same as the input.

Input

ε=0.1^2 ε=0.2^2 ε=0.4^2

Fig.1 Output of Guided filter

The above results show the effect of the blur degree ε. The areas with variance much smaller than ε are smoothed, whereas those with variance much larger than ε are preserved.

VII. CONCLUSION

In this paper, we have presented a novel explicit image filter which can be used in various image processing applications. Guided filter is generic concept for edge preserving smoothing and structure transferring filtering. It is more effective as compared to other existing approaches in aspects such as detail enhancement, denoising, etc. With proper selection of parameter values depending upon the area of application desired results can be obtained.

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