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Effect of the regularization parameter on image-guided filter

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ABSTRACT

Guided filter is derived from a local linear model. It computes the filtering output by considering the content of a guidance image (self-image or reference image). The guided filter can be used as an edge-preserving smoothing operator that behaves better near edges. It can transfer the structures of the guidance image to the filtering output, enabling new filtering applications like dehazing and guided feathering. Moreover, the guided filter naturally has a fast and non-approximate linear time algorithm, regardless of the kernel size and the intensity range. Regularization parameter (ϵ) is one of the two important factors which determines the characteristics of the guided image applied to the input image i.e. it helps to perceive the degree of the edges of an image. In this paper, we will observe the effect of the regularization parameter on a guided filtered image.

Keywords— *Guided Filter, Regularization Parameter (ϵ), Local Linear Model, Edge-Preserving Filtering*

1. INTRODUCTION AND OBJECTIVES

Guided filter is a type of filtering process in which the output locally a linear transform of a guidance image or reference image. The guided filter maintains edge-preserving smoothing properties, like a bilateral filter, and it can also provide smoothing effect to an image. Guided filter used for various applications, like image smoothing / enhancement, HDR compression, flash/no-flash image, matting/feathering, dehazing & join upsampling. It has an $O(N)$ time (in the number of pixels N) *nonapproximate* algorithm for gray-scale and high-dimensional image. The guided filter depends on two factors that determines the filtering output, square window of radius r and regularization parameter (ϵ). In this paper, we will observe the effect of the regularization parameter on a guided filtered image.

2. METHODS

$$E(a_k,b_k) = \sum_{i \in \omega k} ((a_k I_i + b_k - p_i)^2 + \epsilon a_k^2)$$

The above equation is a linear ridge regression model, which involves a guidance image $\boldsymbol{I}$, a filtering input image $\boldsymbol{p}$, and output image $\boldsymbol{q}$. Image $\boldsymbol{q}$ is a linear transform of I in a window $\boldsymbol{\omega_k}$ centred at pixel $\boldsymbol{k}$. ($\boldsymbol{a_k},\boldsymbol{b_k}$) are some linear coefficients assumed to be constant in $\boldsymbol{\omega_k}$. To determine ($\boldsymbol{a_k},\boldsymbol{b_k}$), we need constraints from $\boldsymbol{p}$. $\boldsymbol{\epsilon}$ is the regularization parameter penalizing large $\boldsymbol{a_k}$. When $I \equiv p$, $a_k = \sigma^2{}_k / (\sigma^2{}_k + \epsilon)$ and $b_k = (1 - a_k)\mu_k$. It is clear that if $\epsilon = 0$, then $a_k = 1$ and $b_k = 0$. Two cases are observed when $\epsilon > 0$.

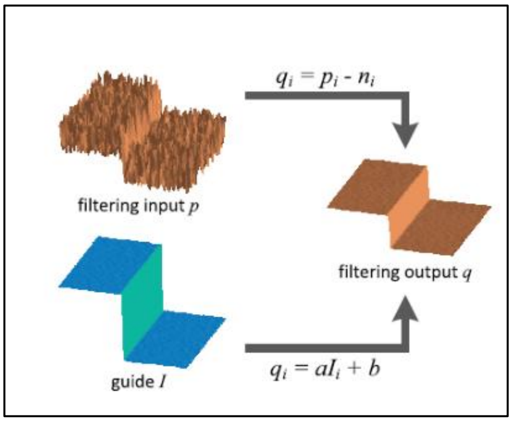

Fig. 1: Basic mechanism of Guided filtering [1]

Case 1: 'High variance.' If the image I varies with ω_k, we have $\sigma^2_k >> \epsilon$, so $a_k \approx 1$ and $b_k \approx 0$.
Case 1: 'Flat patch.' If the image I remains almost constant with ω_k, we have $\sigma^2_k << \epsilon$, so $a_k \approx 0$ and $b_k \approx \mu_k$.
The patches with variance (σ^2) much smaller than ϵ are smoothed, whereas those with larger value of ϵ are preserved. The effect of ϵ is observed using the qualitative and quantitative table below when the radius of the square window (r) is 10.

3. RESULTS AND DISCUSSION

In this experiment, we kept the radius of the square window same throughout the procedure, i.e. $r = 10$. A mirror image of the figure 'Original' is taken which gone through some specific operation to attain the credibility to act as *guidance image* for the experiment. This guidance image guided the fig. 'Original' with considering the constant r and varying regularization parameter (ϵ) to obtain the guided images shown in the following *qualitative table*. By doing this, we observed the quality of the resulting images with quantitative assessment as shown in fig. in *qualitative table* and table in *quantitative table*. It is clear from the result, when the edges of the guided image became more prominent, the similarity between the original and guided image is decreasing, which shown in the *quantitative table*.

3.1 Qualitative results with radius of square window (r) = 10

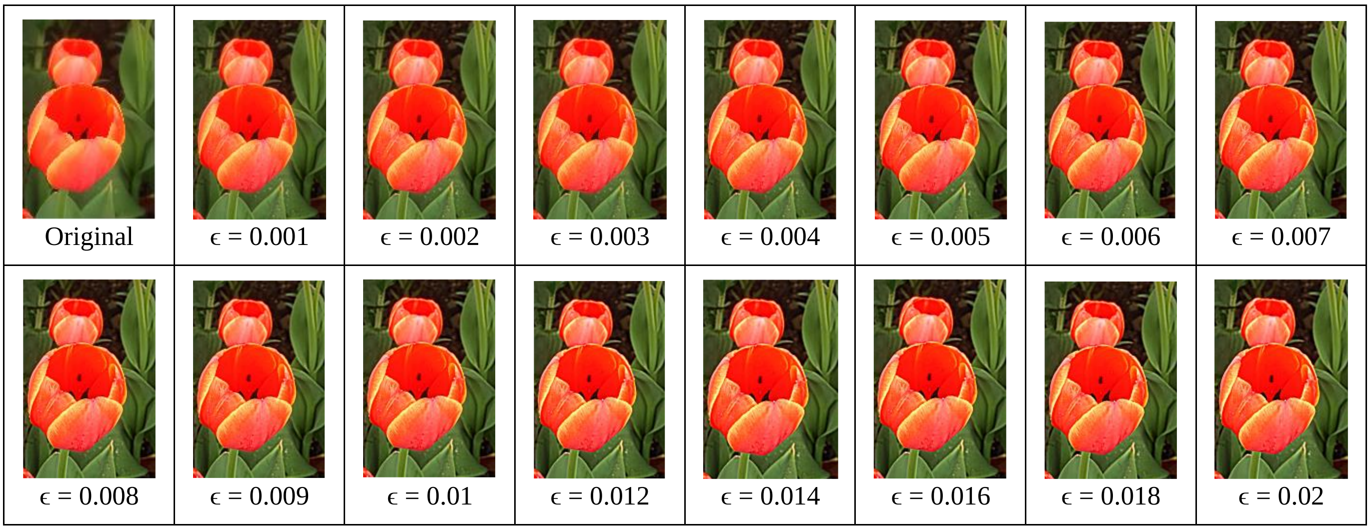

Fig. 2: Performance of original image (Left, top row) with different (15) regularizing parameters with ϵ (0.001 - 0.02) using Guided Filter

3.2 Quantitative Analysis

Table 1: Quantitative evaluation of original image as above in figure 2

Radius of square window (r) = 10															
Regularization Parameter (ϵ)	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.01	0.012	0.014	0.016	0.018	0.02
SSIM	0.9762	0.9636	0.9546	0.9477	0.9371	0.9371	0.9329	0.9292	0.9258	0.9228	0.9175	0.9129	0.9089	0.9053	0.9021
PSNR	30.8065	28.3941	27.0767	26.1840	25.5152	24.9837	24.5448	24.1721	23.8491	23.5647	23.0826	22.6849	22.3476	22.0557	21.7992

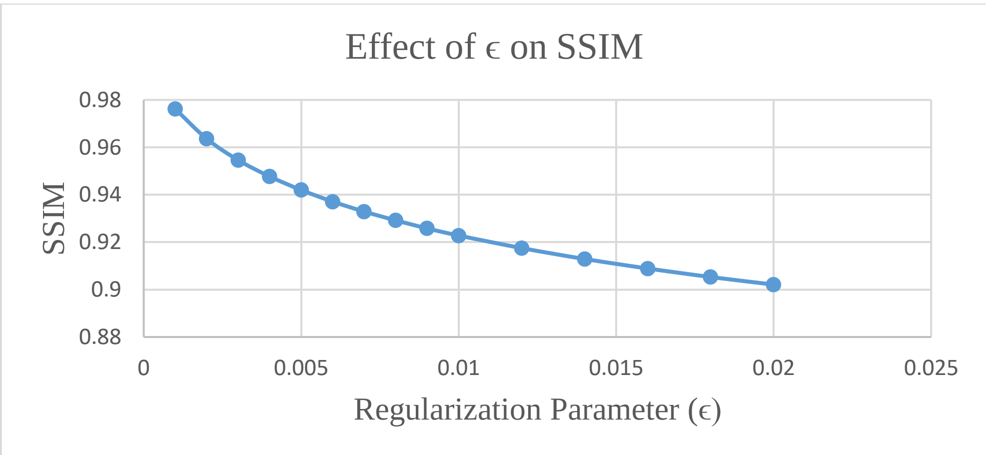

Fig. 3: Graphical representation of SSIM as in table 1

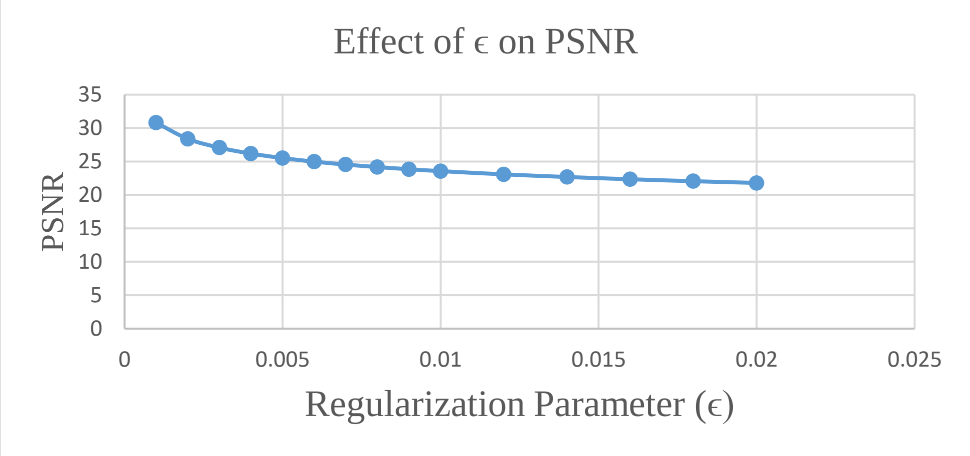

Fig. 4: Graphical representation of PSNR as in table 1

Performance evaluation indicates accuracy, robustness, sensitivity and efficiency. In this work, parametric performance has been evaluated with some parameters such as SSIM and PSNR. The Structural Similarity Index (SSIM) is a perceptual metric that quantifies image quality degradation caused by processing. The Peak Signal-to-Noise Ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. When the reference image is same as the input image, SSIM and PSNR are *1* and *infinite* respectively, whose value decrease with the increase in the dissimilarities between the two images. As shown in *Table 1*, with the change of ϵ, SSIM and PSNR changes or decreases.

4. CONCLUSION

In this paper, we have presented the effect of the regularization parameter in a guided filter. PSNR and SSIM are two functions in MATLAB which are used to determine the image quality or loss of quality with the encoding process of the filtered image to the original image. Both PSNR and SSIM decreases with the increase of ϵ as shown in the *figure 3* and *4*. They both represents the human visual perception. The original image is seem to be slightly blurred when ϵ is less or absent. With the increase of ϵ, the edges becomes more sharpen and enhance the image but after a certain value of ϵ, the filtered image become unpleased to the human eyes. For better human visual perception, optimization is required. For that, more in-detailed work is under process in future work.

5. REFERENCES

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