An optimal performance investigation for bilateral filter under four different image types

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Abstract—The merit of bilateral filter is that it preserves the edges of the image and smooth the image at the same time. This can be done by controlling two important parameters — spatial domain parameter and range domain parameter. The contribution of this paper is two-fold. First, we investigate the optimal parameters of the bilateral filter under four different types of images — aerial, face, object and texture. The simulation results show that the parameters — spatial domain parameter and range parameter — should be changed depending on the noise power and the details of image. If the noise power is high, the parameters should be set at high levels. These values should be decreased on the increasing in an SNR. Second, we determine the appropriate types of image that the bilateral filter can be applied to perform filtering. Then, we compare bilateral filter’s performance to Gaussian filter and switching bilateral filter. The simulation results show that the bilateral filter gives the best performance when perform de-noising of aerial, face and object image where the detail of these images are less than texture image.

Keywords—Image restoration; non-linear filter; range domain parameter; spatial domain parameter.

I. INTRODUCTION

Visual information — image and video — has become more important and utilized in daily life over the years. Most of information that people used to communicate to each other are in the form of images. Moreover, these visual information also be used to diagnose the patient’s symptom. An ever increasing of visual information usage comes with an image quality demand. Nevertheless, the image could suffer from a degradation caused by noise during information transmission, acquisition or recording [1]. Therefore, these poor quality images have to be improved. The methods — image restoration and image enhancement — are used to improve the image quality.

Normally, the quality of the image is degraded caused by noise. An additive white Gaussian noise (AWGN) causes a changing in the image intensity at each pixel where the effect of AWGN distributes over the time varying with a zero-mean Gaussian distribution behavior. Once the noise occurs, it is represented in both high-frequency and low-frequency component of the image and it needs to be removed. In general, a high frequency component is easy to be removed while a low-frequency component is difficult to be distinguished between the component and a desired image.

The image restoration method — image de-nosing [3-29] (or filtering) — is proposed to remove the noise in the image. Generally, image de-noising techniques can be categorized to two types including linear filter and non-linear filter. This kind of filter is appropriate to different type of noise such as non-linear filter gives high performance to remove an impulsive noise while gives the poor performance to remove an AWGN noise. A well-known non-linear filter, median filter [2], filters the noisy image by considering a median value of the neighboring pixels. By this filtering process, the median filter can preserve edges of image. On the other hand, a linear filter gives high performance in AWGN noise removal but gives worse performance in impulsive noise removal. A well-known linear filter, Gaussian filter [3] filters the noisy image by averaging the neighboring pixels and the value becomes the output of the filter.

In this paper, we focus on the performance of a bilateral filter [4-12], which has gained popularity in the image restoration field rapidly, and an alternative solution — switching bilateral filter [13-15] — to improve the performance of the bilateral filter. The bilateral filter is a non-linear filter that can smooth (de-noise) the image while the edges of the image is preserved. The bilateral filter performs filtering based on a frame work of the Gaussian filter which is weight average neighboring pixels and the output becomes new value of the filtered pixel. However, by averaging all of the neighboring, the output of the image may be blur at the edges. Two important components of the bilateral filter — linear component and non-linear component are used to filter a noisy image. The framework of the non-linear component is used to preserve the edges of image while the linear component selects neighboring pixels that has similar intensity to the others and the selected neighboring pixels are weight averaged. The averaged value becomes the output of the filter.