Empirical Exploration Achievement of Noise Removal Algorithm Based on Trilateral Filter for Both Gaussian and Impulsive Noise Ambiance††

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Abstract— **Although the Bilateral filter is one of the most realistic and virtuoso noise removal algorithms, which is often proposed for Gaussian noise in 1998, the Bilateral filter (BF) ineffectively works under the impulsive noise. Consequently, Trilateral filter (which is a modification Bilateral filter) was first proposed by Roman Garnett et al. in 2005 and this filter is based on the hybrid consisting of Bilateral filter and Rank-Ordered Absolute Differences (ROAD) statistic for automatically attenuating or excluding of Gaussian and impulsive noise. Thereby, this research paper empirically explores the efficient influence impact of these four parameters (spatial, radiometric, ROAD and joint impulsivity variance) of the Trilateral filter (TF) when this Trilateral filter (TF) is used for noise removal prospective attitude. In the noise removal exploration, Trilateral filter (TF) is used for five noisy standard images (Girl-Tiffany, Pepper, Baboon, House and Resolution) under five Gaussian noises and five Impulse noise, compared with state-of-the-art algorithms such as Bilateral filter (BF) and median filter. Subsequently, the highest result in the PSNR prospective attitude is nominated. Supplementary, an empirically exploration optimal value of ROAD variance and joint impulsivity variance that yield the highest PSNR is empirically explored for each images and each noise cases.**

Keywords— Trilateral filter (TF), Bilateral filter (BF), Rank-Ordered Absolute Differences (ROAD), Digital Image Processing

I. Review of Trilateral Filter For Noise Removal Fundamental Concept

The main objective of noise removal algorithm is to build a noise-free original image from a noisy image, which is often observed or measured under the noisy environment, by attenuating or excluding noise from the noise-free original image. Although this noise removal problem, so called denoising problem, is a conventional enquiry subject, this problem has been operational enquiry subject in the last decade because the noise removal algorithm is an essential process in several applied Digital Image Processing (DIP) such as remote sensing, facial recognition, etc.

One of the most realistic and virtuoso noise removal algorithms is the Bilateral filter [13], which is often used for Gaussian noise, but the Bilateral filter ineffectively works under the impulsive noise. In 2005, Roman Garnett et al. [6] first proposed a Trilateral filter (which is a modification Bilateral filter) based on the hybrid consisting of Bilateral filter and Rank-Ordered Absolute Differences (ROAD) statistic for automatically suppressing of Gaussian noise, impulsive noise and Gaussian-impulse combination noise. Later, Hancheng Yu et al. [2] proposed a two state filter based on Rank-Ordered Relative Differences (RORD) statistic, which is an another improved ROAD statistic, and a weighted mean filter for suppressing random-valued impulse noise in 2008. Subsequently, Neha Jain [5] proposed an adaptive two phases Trilateral filter in 2009, which is another improved Trilateral filter, based on ROAD and ROLD (Rank-Ordered Logarithmic Differences) [12] for detecting Gaussian noise, impulsive noise and Gaussian-impulse combination noise, especially random-valued impulse noise because the ROAD statistics cannot distinguish the noisy pixel (corrupted by random-valued impulse noise) from the noise-free pixel. Due to large processing complexity of ROLD statistics, V.R. Vijaykumar et al. [9] proposed a two stage filter based on ROAD and adaptive window-size median filter for suppressing scratches, streaks, stripes and impulse noise in 2010. Next, Herng-Hua Chang [3] proposed an improved Trilateral filter, so called an entropy-based trilateral (EnTri) filter, using a median metric weighting function and entropy function for optimizing each weight contributions in 2010. In 2011, Guangyu Xu et al. [1] proposed another improved Trilateral filter based on Rank-ordered Absolute Differences (ROAD) statistics with Extremum Compression, so called EC-ROAD and the EC-ROAD statistics can successfully determine each image pixel as either an impulse or an non-impulse pixel. Later, Tadahiro Azetsu et al. [7] mathematically presented a Trilateral filter in the Robust Self-Cross Bilateral Filter (RSCBF) framework in 2013. Subsequently, Meimei Yang et al. [4] applied a Trilateral filter in the preprocessing of Retinal analysis in the automatic Cataract classification framework in 2013. Due to intensively high computational time, Wen-Chung Kao et al. [10] proposed a fast computational technique of Trilateral filter based on a

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