A tour of nonlocal means techniques for image filtering

J. I. de la Rosa Vargas †, *Senior Member, IEEE*, J. J. Villa †, E. González †, and J. Cortez *

† *Universidad Autónoma de Zacatecas, Unidad Académica de Ingeniería Eléctrica, Av. López Velarde No.* 801, *Col. Centro, C.P. 98068, Zacatecas, Zacatecas.*
* *Instituto Tecnológico de Sonora, Campus Náinari, Depto. de Ingeniería Eléctrica y Electrónica, Av. Antonio Caso No. 2266, Col. Villa ITSON, C.P. 85130, Cd. Obregón, Sonora,*
e-mail: ismaelrv@ieee.org

***Abstract*—The present work proposes a review and comparison of different Nonlocal Means (NLM) methods in the task of digital image filtering. Some different alternatives to change the classical exponential kernel function used in NLM methods are explored. Moreover, some approaches that change the geometry of the neighborhood and use dimensionality reduction of the neighborhood or patches onto principal component analysis (PCA) are also analyzed, and their performance is compared with respect to the classic NLM method. Mainly, six approaches were compared using quantitative and qualitative evaluations, to do this an homogenous framework has been established using the same simulation platform, the same computer, and same conditions for the initializing parameters. One will notice that particularly, the BM3D SAPCA approach gives the best denoising results, but in contrast, the computation times of this method were the longest.**

1. Introduction

The image filtering, is a particular task of restoration or recuperation approaches of an image to its original condition given a degraded image. there are challenging problems to construct robust filters in applications where the noise has very large standard deviation or where it is of multiplicative nature such as the speckle type noise [14], [24]. Since 2005, the Nonlocal Means (NLM) filtering has gained some popularity and credibility, because this type of filters deals with the preservation of structure and objects into a digital image [1].

The classic exponential kernel function is used in most of the cases as a weighting function in NLM methods [1], [2], [3], [4] to deal with digital image filtering as it can be seen in equation (4). Moreover, the performance of the NLM depends on an optimal choice of the bandwidth parameter h, and other related parameters such as the size of the neighborhood, and the search region (geometry of patches). An optimal selection of the bandwidth parameter h is a difficult task, this problem has been interestingly solved in the work of Van De Ville and Kocher [29], [30] by using the Stein's unbiased risk estimate (SURE), also one can propose an empirical fixed approximation based on experimental results. Moreover, since h depends on the noise level to have a good performance of the NLM methods, in practice, it is important to estimate the noise distribution or some of its statistical properties, recently some works have reported some performing approaches in this important task [5], [8], [22], [23].

On the other hand, there are some other kernel functions which have other equivalent parameters [15] and they may be used in the NLM context as robust weighing functions as illustrated in [16], [18], [28]. More over, the performance of NLM could be improved by using recent hybrid algorithms which are based on the change of the geometry of the neighborhood of noisy pixels and performing a collaborative filtering, here the notion of block-wise or patch-wise filtering plays an important role in NLM, since the methodology can be improved as shown in works of Deledalle et al. [13], [14], and the successful BM3D method proposed by Dabov et al. [6], [7]. In the present paper we propose the review and performance comparison of different Kernel functionals and hybrid methods. First, one is interested to answer the following questions: what happens with the performance of NLM methods if one changes the kernel structure? And a second question is, what happens when one changes the geometry of the searching region for NLM? To answer both questions, some comparisons were performed with respect to the classic NLM method, to do this an homogenous framework has been established using the same simulation platform, the same computer, and same conditions for the initializing parameters, such as the seed to generate the noise random samples which will be added to free-noise database images.

The paper is organized into the following sections: Section 2 presents the Nonlocal Means filtering technique. Section 3, gives a summarized presentation of patch-wise based NLM. In section 4, the results of NLM filtering are discussed for several approaches and some illustrative results are shown to answer the questions on the use of robust kernels and changing geometry of the searching region into the NLM framework. Finally, in section 5 some concluding remarks are given.

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