Application of noise reduction based on estimation of the noise level function by detecting non-parametrically homogeneous image regions

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Abstract

We propose an image application of noise reduction, which is based on the paper "Estimation of the noise level function based on a non-parametric detection of homogeneous image regions" of [Sutour et al, 2015]. In their research, they proposed an algorithm of estimating automatically the noise level function from a single image and applied in noise reduction with non local means algorithm. In our application, we provide a tool of noise reduction automatic with graphical user interface.

I. Introduction

Our application provides a demonstration of noise level function estimation research with the capacity of creating noise by using the parameters of user, detecting noise level function and denoising image. This application is built on Matlab software. This section describes the general idea of the two-step algorithm in the research mentioned. The approach of this algorithm is based on the fact that natural image has homogeneous regions showing clearly the noise statistics. Therefore, the first matter is non parametric detection of homogeneous image regions [Section 2]. In this case, the image is divided into square regions on which Kendall coefficient detector returns the homogeneous regions. Kendall coefficient is non parametric detection because it is a rank-based measure of correlation independent on noise distribution. The second matter is estimating noise level function based on these homogeneous regions [Section 3]. In detail, noise level function NLF is a second order polynomial of the image intensity in the form $NLF(x) = ax^2 + bx + c$ with the coefficients (a, b, c). For each homogeneous region, its mean and its variance of image intensity are extracted. Preconditioned primal-dual algorithm [Chambolle at al, 2010] updates the coefficients in order to minimizing the least absolute deviation by using these means and variances. The result of this process is the noise level function of the input image which is used in denoising algorithm. The last matter is how non-local means algorithm (NL-Means) applies this function in noise reduction [Section 3]. In fact, this algorithm is adapted in order to use only the knowledge of noise coefficient predicted. As shown above, this two-step algorithm provides the noise level function for the denoising image of NL-Means, which means that the input image is denoised automatically.

II. Non parametric detection of homogeneous image regions

This section presents the homogeneous region detector based on Kendall coefficient. In detail, homogeneous region is a region in image space representing an object which has a homogeneous color [Morh et al, 2007]. This kind of region could show clearly the noise statistics because its noise fluctuation is significantly larger than its signal fluctuation. Kendall rank correlation coefficient evaluates the degree of similarity between two sets of objects [Abidi, 2007], which means that in our case, it computes the similarity of pixel intensities in an image region. Therefore, the Kendall coefficient is capable of deciding whether a region is homogeneous.

In the algorithm mentioned, the input image is divided into a set of square blocks. [Sutour et al, 2015] proposed a practical setting of the square maximum size 16 x 16. Moreover, the block size is reduced if there are not enough number of homogeneous regions. Kendall coefficient evaluates the similarity level between two sets and thus the pairs of sequences including pixel intensities of a region are extracted. In other words, we compute Kendall coefficient by comparing horizontal, vertical and diagonal neighbors of both directions [Figure II.1]. This Kendall coefficient provides a p-value, associated to the rank correlation, which is the probability of a homogeneous region. In this case, there are four p-values of correlation tests in four directions and the probability of the homogeneous region is the minimum of p-value. In practice, the research in [Sutour et al, 2015] proposed a probability threshold 0.6 for selection of homogeneous region.

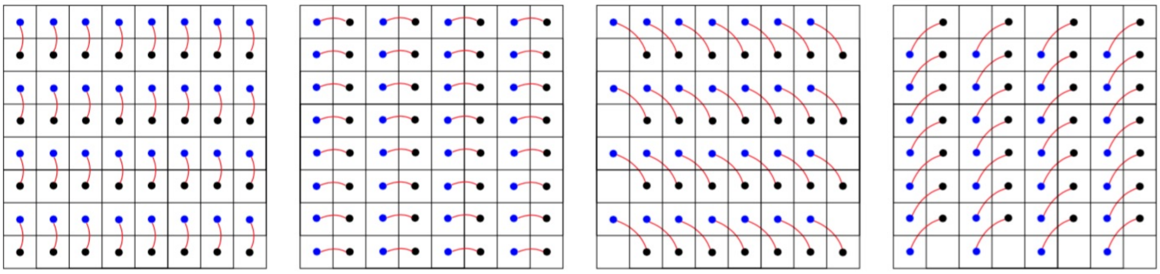

Figure II.1: Pixel selection for homogeneous detection.

III. Noise level function estimation

In this section, we describe the noise level function and the estimation algorithm. To explain, the noise level function is estimated as a second order polynomial function NLF(x) = $ax^2 + bx + c$ with the parameters (a, b, c). It is based on the assumption that the noise is dependent with finite first and second order moments. In this case, the function is a combination of two types of noise Gaussian and Poisson. If (a,b) = 0, NLF represents Gaussian noise because it is constant with NLF(x) = c. If (a,c) = 0, NLF is linear, which shows Poisson noise. If (b,c) = 0, it is multiplicative nose, Gaussian-Poisson and its graph is parabolic. Therefore, NLF could represent the unknown noise distribution on image after the estimation process.

The algorithm proposed for noise level function estimation is the preconditioned primal-dual algorithm for the least absolute deviation. For each homogeneous region detected, its mean (μ) and its variance (σ) are extracted. The purpose is finding the correct value of parameters (a, b, c) with the formula:

$$\sigma^2 = NLF(\mu) = a\mu^2 + b\mu + c$$

which minimizes the least absolute deviation. Therefore, the problem becomes

$$argmin_{\ (a,b,c)} ||NLF(\mu) - \sigma^2|| = argmin_{\ (a,b,c)} ||a\mu^2 + b\mu + c - \sigma^2||$$

In this case, this problem is the convex optimization that the global optimum could be computed. As a result, for each homogeneous region and each iteration predetermined, these parameters a, b, c are updated. After this estimation process, the noise level function determined is used in the denoising algorithm, non-local means.

IV. Non-local means algorithm

This section presents the algorithm Non-Local Means and the version adapted for the knowledge of noise level function. The algorithm NL-Means is proposed in [Buades et al, 2005] which concentrates on the high degree of image redundancy. It is based on the idea that every small region around a pixel I in a natural image has similar regions in the same image. Therefore, the pixels of these similar regions, namely "neighborhood of pixel I", are used for predicting the value of I. In this case, the value of denoised pixel I is

$$value(I) = \sum_{J=Other\ pixels\ in\ image} w(I,J) * value(J)$$

where w(I,J) is the weight of pixel showing the similarity between two pixels I and J. These weights are under two conditions $0 \leq w(I,J) \leq 1$ and $\sum_J w(I,J) = 1$. In fact, the similarity of two pixels is the pixel intensity similarity of two regions around these two pixels.

In the case of knowing NLF, the weight is calculated by the expectation mean, the standard deviation and the dissimilarity of two regions. The expectation mean and the standard deviation are computed by the following steps: Firstly, a noise image is randomly created by NLF. Secondly, a Gaussian filter is applied for denoising this image. Finally, the expectation mean and the standard deviation are computed from this denoised image. As a result,

$$value(I) = \frac{\sum_{J=Other\ pixels\ in\ image} w(I,J) * value(J)}{\sum_{J=Other\ pixels\ in\ image} w(I,J)}$$

$$w(I,J) = \exp\left(-\frac{|\,intensity\ dissimilarity\ (I,J) - expectation\ mean\,|}{standard\ deviation}\right)$$

$$intensity\ dissimilarity(I,J) = \frac{1}{P}\sum_{k=1}^{P}\frac{(g_k^I - g_k^J)^2}{NLF(g_k^I) + NLF(g_k^J)}$$

where P is the size of region or number of pixels in a region, g^I_k is the intensity of pixel k^{th} in the region around I.

V. Noise reduction application

In noise reduction application, we show the illustration of the research [Sutour et al, 2015] which provides the tools of denoising: Creating noise from a noise level function that its parameters are selected by user, estimating the noise level function of an image, denoising image by algorithms NL-Means and filters such as Bilateral, Median, Averaging, Weiner and Gaussian.

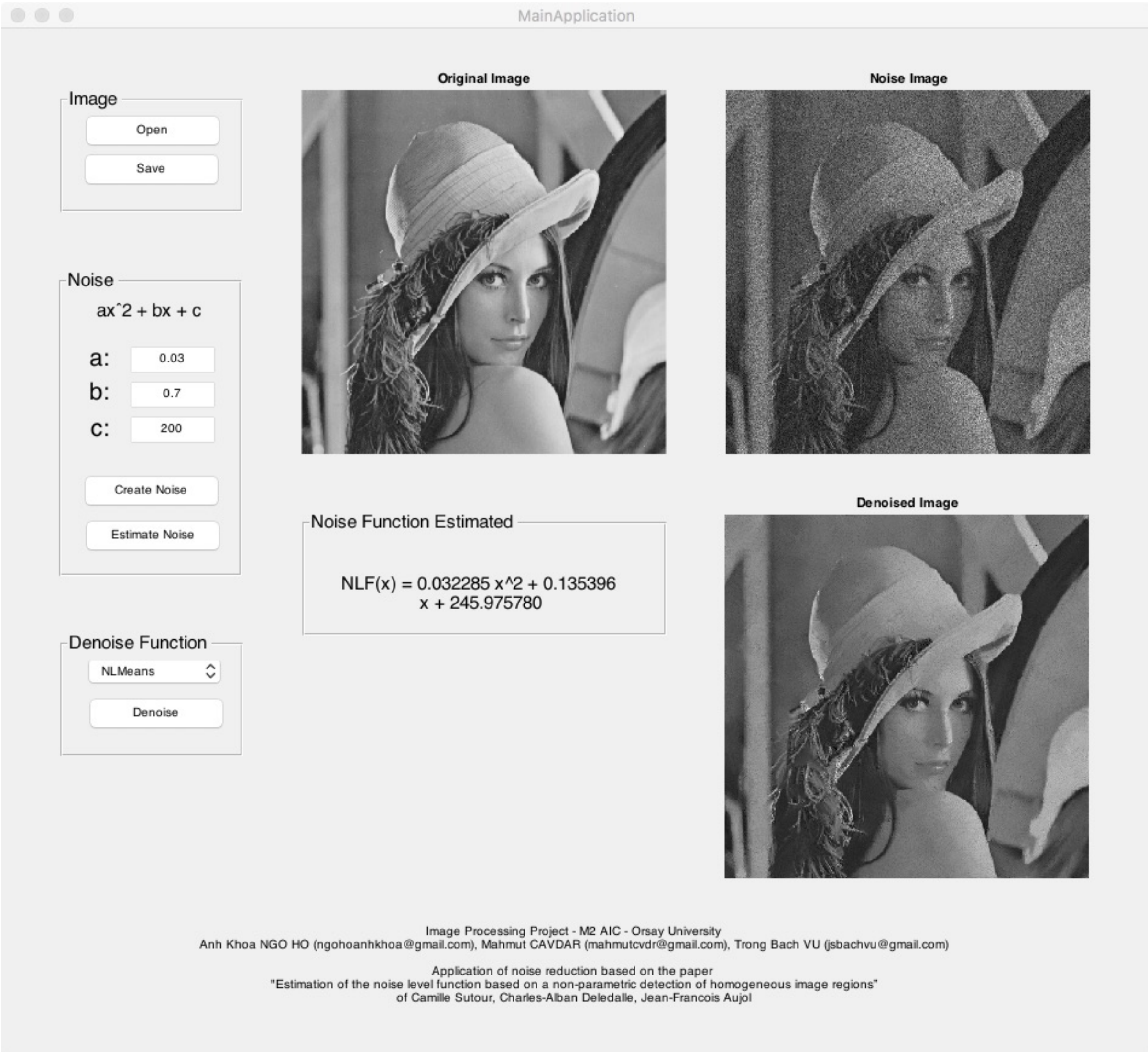

Figure V.1: Application Interface

VI. Conclusion

The research of [Sutour et al, 2015] provides a two-step algorithm, a homogeneous region detection and noise level function estimation. NL-Means is modified for an adaptation of noise level function estimated, which shows a remarkable result. Therefore, the main contribution of this research is a method automatic of noise reduction. Our application with graphical user interface, based on this research, provides an illustration of the two-step algorithm and then a tool of noise reduction.

Reference

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