САМАРСКИЙ УНИВЕРСИТЕТ
SAMARA UNIVERSITY

ITNT - 2023

IX The International Conference on Information Technology and Nanotechnology , 14-21 April, Samara, Russia

Investigation of a denoising method based on sparse representation

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Abstract

This article is devoted to the study of image restoration, using sparse representation. The sparse representation is a description of image in form of coefficients for fragments selected from a predetermined dictionary. This article proposes a general approach to image restoration using sparse representation and presents results of experiments for the simplest implementation of this approach.

Introduction

Noise in image that occurs unexpectedly as a result of analysis of the environment, transmission, and other factors, resulting in transmission and loss of image information. Noise can be changed as redundant noise information in a real image. An excess of such information can appear fuzzy to image and has adversely affected potential image processing issues, such as video processing, image analysis, and tracking.

Image noise reduction improves image quality through a number of techniques, preserving as much of the original information as possible and removing useless information from the signal. The main objective of noise reduction is to reduce noise in images while minimizing the loss of original characteristics and improving the signal-to-noise ratio (PSNR).

The appearance of noise in image cannot be predicted theoretically. Therefore, to describe the process of image noise, the probability distribution function is usually used. The probability density function underlies the description of the statistical characteristics of noise in image processing, and the corresponding data model is established from it.

Existing noise reduction methods can be divided into two groups: based on the analysis of a certain neighborhood (spatial domain methods) and based on image transformation to another area (spatial-frequency domain methods)

In this work, for noise suppression, we use the sparse representation method, which has recently been widely used both in signal processing and in image processing problems.

Sparse Representation

In the present study, an algorithm using a sparse representation of images was used as the basis for the development.

This algorithm assumes that image can be decomposed as follows:

$x = Da$

Here D is a dictionary (matrix) of size $N \times K$. N is the dimension of the simulated signal, K is the size of the dictionary, a is a vector with a small number of nonzero elements no more than L.

Then noise reduction process can be written in the following form:

$$f(x) = \frac{1}{2}\|x - y\|_2^2 + \sum_{j=1}^{K}|a|^p .$$

Each image fragment can be represented as a linear combination of several fragments from the redundant dictionary D.

Proposed approach

By analogy with the method based on the Fourier transform, we can represent the process of sparse representation of image in the following form:

$\hat{a} = S_D(y)$,

where y is original image.

Due to the fact that the dictionary D is redefined, there is such a transformation S_D that:

$y = {S_D}^{-1}(\hat{a})$.

It is achieved by assigning $T_0 = 0$ in the expression

$\hat{a} = \min_a \|a\|_0, \|Da - y\|_2^2 \leq T_0$.

According to the same expression, it is obvious that S^{-1} in this case has the form:

${S_D}^{-1}(\hat{a}) = \sum a_d$.

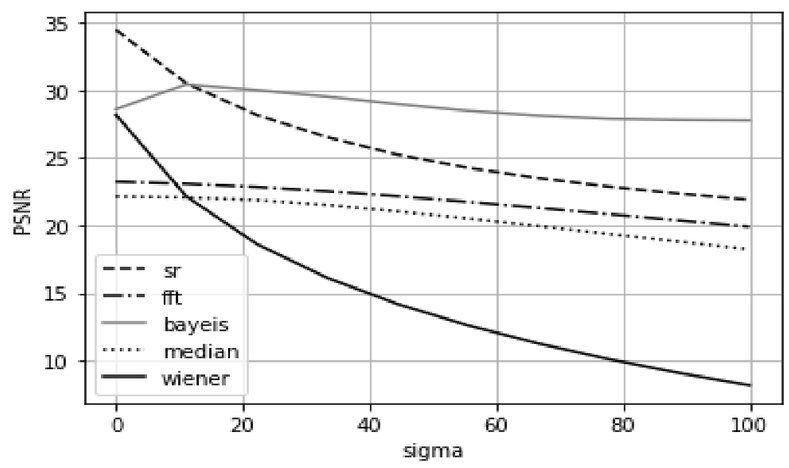
Consider a class of filters represented in the form of a transformation in the space A of sparse representations. The result of applying such a filter is a new image obtained as:

$\hat{Y} = S^{-1}\,(G(S(y))$,

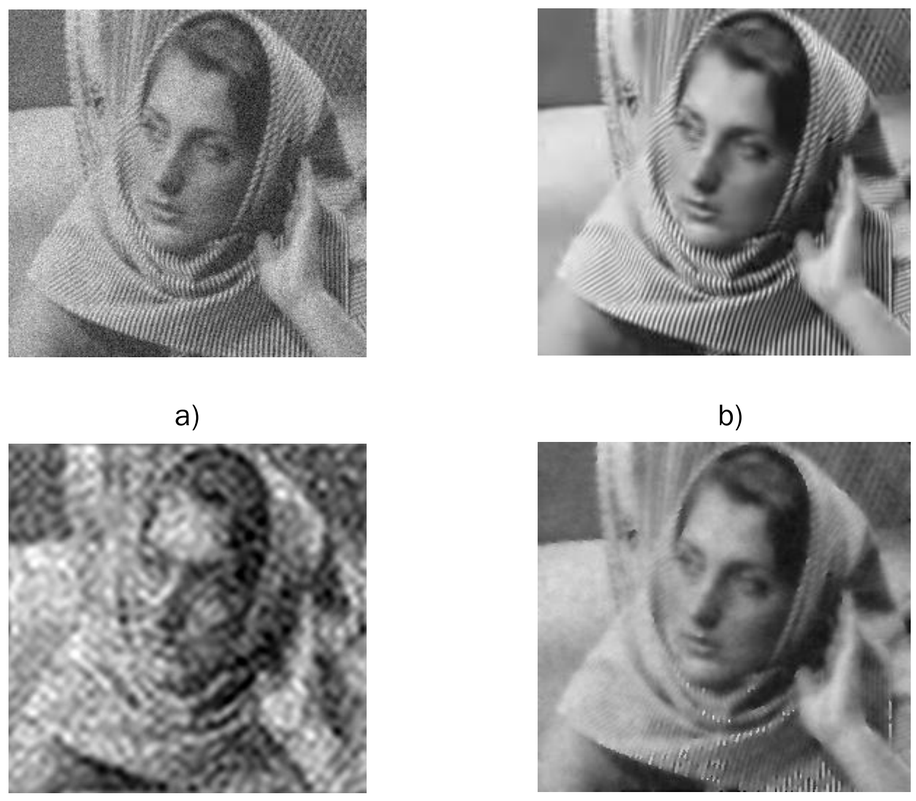
where $G()$ is the transformation in the space of sparse representations.

PSNR Values

Method	σ		
	8	15	25
Noisy	30.1	24.64	20.2
Sparse representation	35.77	32.16	29.24
Fourier transform	23.26	23.17	22.98
Bayesian estimation	28.57	29.69	30.27
Median filter	22.15	22.11	21.99



Recovery result



a) b)

c) d)

Examples of research results are shown in Figure: (a) a noisy image, (b) a reconstructed image using a sparse representation, (c) an image restored using a Fourier transform, (d) an image restored using a Bayesian approach.

Discussion and Conclusion

In this paper, we consider the influence of the degree of noise in the original image on the restoration result obtained using the sparse representation

Acknowledgements

The research was carried out within the state assignment theme 0777-2020-0019.

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