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ScienceDirect

Procedia Computer Science 115 (2017) 526–532

Procedia Computer Science

www.elsevier.com/locate/procedia

7th International Conference on Advances in Computing & Communications, ICACC-2017, 22-24 August 2017, Cochin, India

Constrained least squares filtering followed by denoising of decomposed images using wave atom and wavelet transform

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Abstract

Image restoration is very essential in order to recover an image from its blurred and noisy form. A novel algorithm is proposed here which uses constrained least squares filter for deconvolution followed by denoising section. Deblurred image obtained after deconvolution is decomposed into texture and cartoon parts, using curvelet transform, which are then denoised using wave atom transform and wavelet transform respectively. Cycle spinning technique is used to enhance the denoising capability of wavelets and wave atoms. This algorithm does not require a priori knowledge of the noise distribution and provides effective noise reduction for texture dominant images.

Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances in Computing & Communications.

Keywords: Constrained least squares filtering; curvelet transform; cycle spinning; image decomposition; wave atom transform; wavelet transform.

1. Introduction

Image restoration is the process of recovering an image from its degraded form. Different techniques such as deblurring and denoising are used for this purpose. Deconvolution methods minimize blur as well as noise. If the information regarding the point spread function is not known, deconvolution is said to be blind and if it is known, then it is said to be non-blind.

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1877-0509
Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances in Computing & Communications
10.1016/j.procs.2017.09.110

Parametric Wiener filtering followed by wave atom transform [1], denoising by supervised adaptive fusion of decomposed images [2] are some of the recent related works. Image denoising based on wave atoms and cycle spinning [3] shows the advantage of using cycle spinning. In another work, variable splitting fast image recovery (VSFIR) has been introduced to obtain an equivalent constrained optimization formulation, addressed with an augmented Lagrangian method [4]. TV-BDSB is a new TV (total variation) blind deconvolution method which is employed using split Bregman iteration [5]. For non-local TV regularization problems, algorithm is presented based on operator splitting technique and Bregman iteration [6]. Non-blind image deblurring (NBID) is a method that has been introduced to preserve the salient edges during restoration [7].

Restoration using Wiener filtering [8], [9] requires both the information regarding noise as well as that of blur to obtain the estimate of original image. The proposed work deals with the restoration of degraded images where the information regarding the noise is unknown. Constrained least squares filter is hence used here for deconvolution. After filtering process, the deblurred image is decomposed into texture and cartoon parts using curvelet transform. The decomposed texture part is denoised using wave atom transform taking the advantage of cycle spinning while the decomposed cartoon part is denoised using wavelet transform with cycle spinning. The denoised texture and cartoon parts are then fused to form the final denoised image. Cycle spinning is a technique that has been used in order to overcome the distortions that occur during denoising by coefficient thresholding. Wave atoms denoise oscillatory patterns and textures while wavelets denoise cartoon parts in an image effectively. So combining constrained least squares filter, wave atoms, and wavelets along with cycle spinning provides better restoration results.

2. Description

2.1. Degradation and Wiener filter

The process in which an image is affected by blur and noise is called degradation. Let f be the clear image degraded by a degradation function H, and additive noise n, thus a noisy blurred image g is formed.

$$g = f * H + n \tag{1}$$

Wiener filter requires statistical noise characteristics and degradation function for image restoration process where noise and image are assumed to be uncorrelated. The objective of this filter is to find the estimate of clear image f to minimize the mean square error. Frequency domain solution for Wiener filter is given by the following transfer function:

$$\hat{F}(u,v) = \left[\frac{H^*(u,v)}{|H(u,v)|^2 + \dfrac{N(u,v)}{I(u,v)}} \right] G(u,v) \tag{2}$$

$H(u, v)$ is the degradation function, $H^*(u, v)$ is its complex conjugate, $G(u, v)$ is the noisy blurred image, $N(u, v)$ is the noise power spectrum and $I(u, v)$ is the power spectrum of original image. $N(u, v) / I(u, v)$ is known as noise to signal power ratio.

2.2. Constrained least squares filter

Constrained least squares filter is an extension of Wiener filter where the deconvolution does not require information of the noise. Its frequency domain solution is given by the following transfer function: