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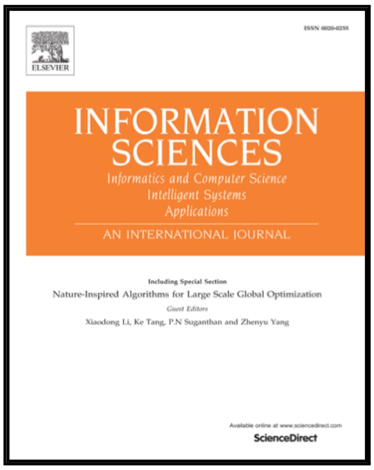

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Rank Minimization with Applications to Image Noise Removal☆

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Abstract

Rank minimization problem has a wide range of applications in different areas. However, since this problem is NP-hard and non-convex, the frequently used method is to replace the matrix rank minimization with nuclear norm minimization. Nuclear norm is the convex envelope of the matrix rank and it is more computationally tractable. Matrix completion is a special case of rank minimization problem. In this paper, we consider directly using matrix rank as the regularization term instead of nuclear norm in the cost function for matrix completion problem. The solution is analyzed and obtained by a hard-thresholding operation on the singular values of the observed matrix. Then by exploiting patch-based nonlocal self-similarity scheme, we apply the proposed rank minimization algorithm to remove white Gaussian additive noise in images. Gamma multiplicative noise is also removed in logarithm domain. The experimental results illustrate that the proposed algorithm can remove noises in images more efficiently than nuclear norm can do. And the results are also competitive with those obtained by using the existing state-of-the-art noise removal methods in the literature.

Keywords: Rank minimization problem; Nuclear norm; White Gaussian additive noise removal; Gamma multiplicative noise removal; Nonlocal self-similarity; Block matching
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1. Introduction

Rank minimization exists in a wide range of scientific applications such as controller design, system identification, computer vision and machine learning, etc. See, for instance, [19]. More recently, based on the idea of nonlocal self-similarity between patches in a noisy image, rank minimization problem has been actively applied in image denoising and significant recovering effects have been made, see, for instance, [22, 25, 27]. In this section, we give a review of matrix rank minimization problem and its applications in image restoration.

1.1. Rank Minimization Problem

Rank minimization problem is generally formulated as:

$$\begin{aligned}&\min \operatorname{rank}(X),\\&\text{s.t. } X \in \mathscr{C}.\end{aligned}$$

Where $\operatorname{rank}(\cdot)$ is the rank of the given matrix, $X \in \mathbb{R}^{n_1\times n_2}$ is the unknown low-rank matrix, $\mathscr{C}$ is a convex set. Since rank minimization problem is NP-hard and non-convex [3], it is difficult to describe a general solver for such a problem. Efficient algorithms have been constructed for some special rank minimization problems in the

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