International Journal of Computer Vision
https://doi.org/10.1007/s11263-023-01840-8

STP-SOM: Scale-Transfer Learning for Pansharpening via Estimating Spectral Observation Model

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Received: 3 September 2022 / Accepted: 14 June 2023

Abstract

Pansharpening strives to improve the spatial resolution of multi-spectral images while maintaining spectral fidelity. However, existing methods usually cannot guarantee a balance between spatial and spectral quality, and degrade when handling the desirable scale of full resolution. To address these challenges, this prospective study proposes a scale-transfer learning framework via estimating spectral observation model. Specifically, we design a cross-spectral transfer network to learn an expected spectral observation model by the cycle adversarial between spectral degradation and interpolation, which describes the accurate nonlinear mapping process from multi-spectral to panchromatic images. Having the favorable spectral observation model established, a scale-transfer pansharpening paradigm with co-learning of full and reduced resolutions can be constructed. First, we develop a spectral observation model-based spatial fidelity term at the reduced-resolution scale, which can alleviate the imbalance problem of spectral and spatial information widespread in current supervised paradigms. Second, we explore the reprojection regularization from full to reduced resolution based on the spectral observation model, which facilitates the ability of the pansharpening model to be extended to the scale of full resolution. Extensive experiments demonstrate the advantage of our method over the current state-of-the-arts in terms of information balance and scale transformation. We further apply our method to produce the high-resolution normalized difference vegetation index and achieve vegetation enhancement with competitive performance. Moreover, our method is lightweight and faster than other comparative methods.

Keywords Pansharpening · Scale-transfer · Cross-spectral transfer · Spectral observation model · Reprojection regularization

1 Introduction

The demand for remote sensing images with both high spatial resolution and high spectral resolution exists widely and urgently in various fields, such as land cover mapping and environment monitoring (Garzelli et al., 2018; Zhang et al., 2013). Unfortunately, the spectral and spatial resolution is often incompatible because of the imaging hardware. For instance, the current multi-spectral (MS) sensors in satellites cannot guarantee spatial resolution, because the spectroscopic/filter mechanism requires a large instantaneous field of view (IFOV) to meet the requirement of signal-to-noise ratio (SNR) (Li et al., 2022). In this case, the pansharpening technology emerged to combine the panchromatic (PAN) and MS images, generating the desired high-resolution (HR) MS image, as shown in Fig. 1. Due to its solid foundational role in the field of remote sensing, pansharpening has been a research focus from the past to the present (Ghassemian, 2016; Meng et al., 2019).

With the rapid development of computational imaging technology in recent decades, a variety of pansharpening algorithms have been developed (Deng et al., 2022; Javan et al., 2021; Yilmaz et al., 2022; Zhang et al., 2021). According to their principles, these methods can be divided into three categories. (i) Model-based methods. Methods of this kind usually optimize the preservation of spatial and spectral information through inverse constraints based on existing spectral and spatial observation models (Fu et al., 2019; Jiang et al., 2015), in which the spectral observation model indicates the transformation function from MS to PAN images, while the spatial observation model denotes the degradation process from HRMS to low-resolution (LR) MS images.

Communicated by Michael Ying Yang.

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Published online: 12 August 2023