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SSANU-Net: Spatial-Spectral Additive Nonlinear Unmixing Net

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Abstract:

Hyperspectral unmixing (HU) plays an important role in the hyperspectral image (HSI) processing and analysis. It aims to decompose mixed pixels into pure spectral signatures and their associated abundances. The autoencoder (AE) framework achieves good performance in HU by automatically learning low-dimensional embedding and reconstructing data. Most of the existing HU methods based on the AE framework can be divided into two categories, one is the pixel-to-pixel network focusing on the spectral information of HSI, and the other is the 2DCNN network focusing on the spatial information of HSI. However, HSI contains both spatial and spectral features, it is helpful to add both spectral and spatial information into unmixing methods. Besides, most of the existing unmixing methods are based on linear mixed models (LMM). In LMM, the incident light is assumed to be reflected by each component present in the scene only once prior to collection by the camera sensor, and the observed spectrum is thus a linear combination of the endmembers. However, the real scene is often complex, and due to the existence of spectral variability (SV) and photon nonlinear interaction, the assumption of LMM is often not valid (Zhao et al., 2022). As a result, the LMM hardly makes an accurate unmixing in reality. The excellent potential of neural networks to solve nonlinear problems provides the possibility to establish nonlinear mixed models, which may solve this problem.

Herein, this paper proposes a Spatial-Spectral Additive Nonlinear Unmixing Net i.e., SSANU-Net (Figure 1). The network is based on the AE framework, which obtains a set of fractional abundances through the encoder and obtains the reconstructed image through the decoder. Specifically, the encoder consists of a spatial-spectral two-stream network, which can learn the spatial and spectral features of the image separately and better distinguish different objects by adaptively weighting the learned spatial and spectral features. Besides, the decoder consists of a linear-nonlinear dual-stream network, which can simulate the linear and nonlinear components of the interaction between photons respectively, and adaptively weight the simulated linear and nonlinear components through learnable parameters, which can be applied in different real scenarios.

Experiments are conducted on two real datasets and compared with the existing four traditional and state-of-the-art unmixing methods. The results (Figure 2) show that the proposed method has the higher unmixing accuracy. We also evaluated the impact of noise on the proposed method. Experiments on synthetic data set with 0dB, 20dB, and 40dB show that the proposed method has high robustness, and the RMSE fluctuation under different noises does not exceed 0.005. Ablation studies show that the spatial-spectral characteristics of images in different scenes and the linear-nonlinear interaction of photons have different degrees of influence on the accuracy of spectral unmixing. The proposed method comprehensively considers the above four factors, has strong generalization ability, and is expected to maintain high unmixing accuracy in different real scenarios.

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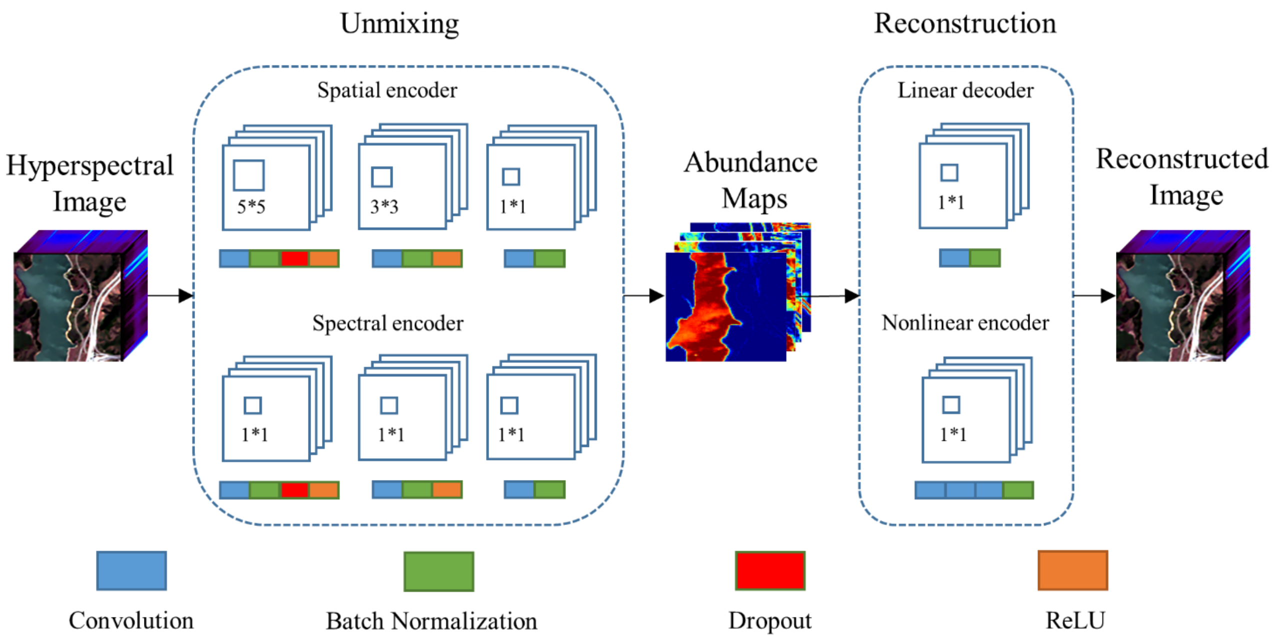

Figure 1. The architecture of our proposed framework. It consists of two parts: encoder and decoder.

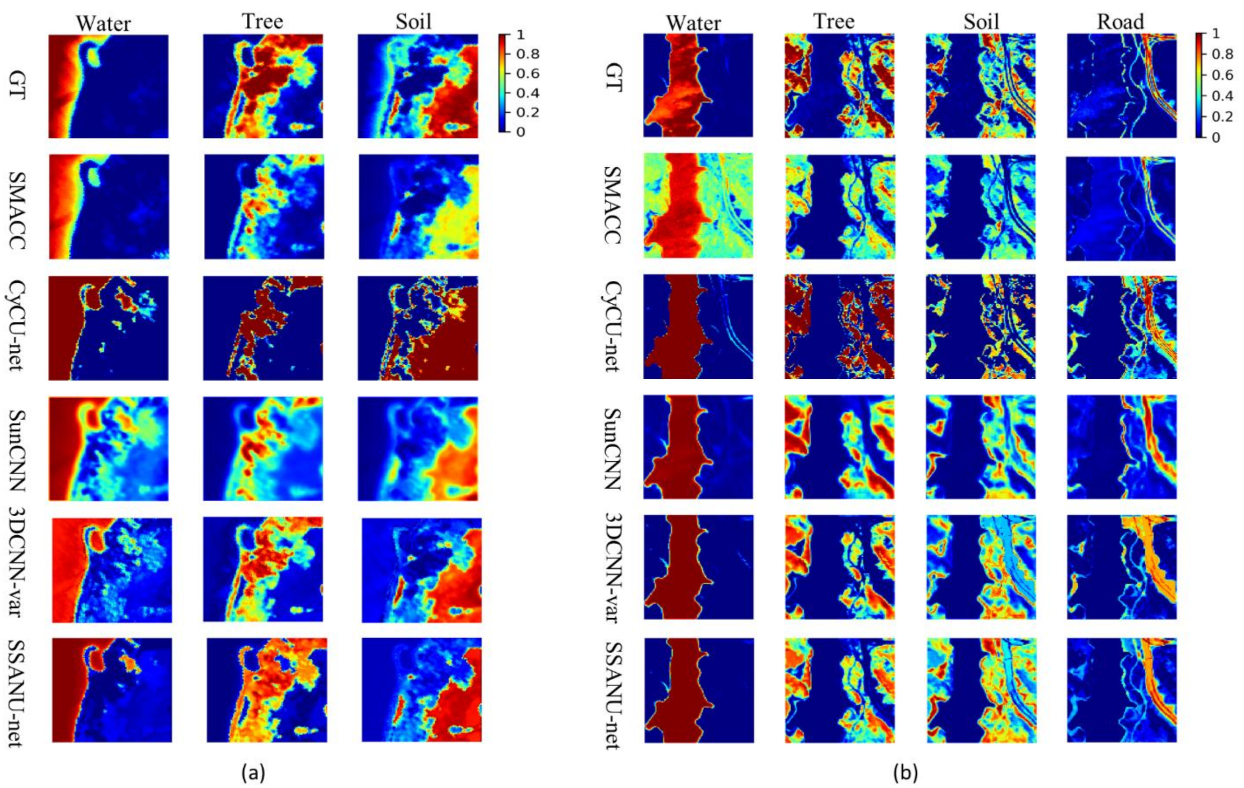

Figure 2. Visualization of abundance maps using different unmixing methods on two real datasets: (a) is the Samson dataset, (b) is the Jasper Ridge dataset

References

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