Nonlinear Hyperspectral Unmixing Based on Generative Adversarial Network

Qiwen Jin, Jiwei Hu, Ping Lou and Kin-Man Lam

***Abstract*—Spectral unmixing (SU), which refers to extracting basic features (i.e., *endmembers*) at the subpixel level and calculating the corresponding proportion (i.e., *abundances*), has become a major preprocessing technique for hyperspectral image analysis. In this article, we propose a novel technique network for unsupervised unmixing based on the adversarial autoencoder, termed as BNNet. To enhance the model's applicability and generalization performance, in the construction of the network's nonlinear framework, the model decoder is designed as a universal spectral mixing model consisting of linear mixture components and additive nonlinear mixture components. This allows the network to adaptively learn the linear and nonlinear proportion weights in the scenario. The specific nonlinear mixing parameters are learned from the original data, rather than relying on fixed model assumptions.**

I. Introduction

Hyperspectral unmixing is a crucial task in analyzing hyperspectral data, which aims to estimate the abundance fractions of different materials (endmembers) present in each pixel. Traditional unmixing methods often assume linear mixing models, which may not accurately represent the complex nonlinear mixing behavior in real-world scenarios[1]. In this study, a novel approach combining deep autoencoder networks and superpixel segmentation is proposed for hyperspectral unmixing[2].

II. The Proposed Method

The proposed method consists of two main steps: superpixel segmentation and deep autoencoder network-based unmixing. Superpixel segmentation is employed to group pixels with similar spectral characteristics into compact regions, which helps to reduce the computational complexity and improve the accuracy of unmixing. The deep autoencoder network is trained to learn a low-dimensional representation of the hyperspectral data, which captures the underlying nonlinear mixing behavior. The network is trained using an unsupervised learning approach based on adversarial autoencoder networks. The architecture of the proposed BNNet Network is illustrated in Fig. 1.

III. Experimental Results

The proposed method is evaluated on both synthetic and real hyperspectral datasets. In the synthetic dataset experiments, the proposed method achieves superior unmixing accuracy compared to several state-of-the-art algorithms, including MLM, semi-NMF, NAE, DeepGUn, FCLS, and BNNet. The results demonstrate the effectiveness of the deep autoencoder network in capturing the nonlinear mixing behavior and accurately estimating the abundance fractions of endmembers. The specific quantitative unmixing accuracy values on Cuprite dataset are shown in Table I.

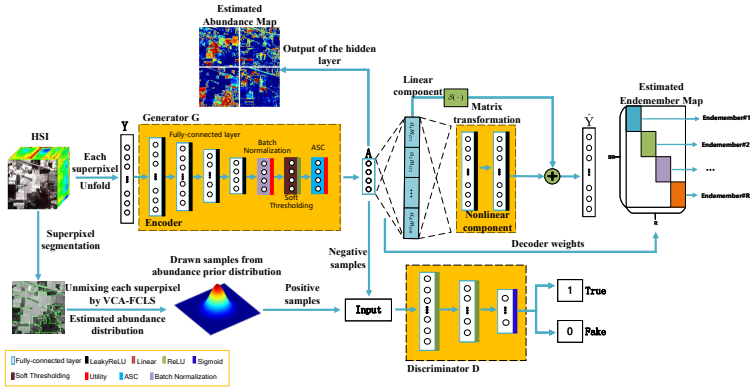

Fig. 1. The architecture of the proposed BNNet Network

TABLE I
Comparison of unmixing accuracy between endmember SAD and pixel reconstruction RMSE on Cuprite dataset.

Endmember	MLM	semi-NMF	NAE	DeepGUn	FCLS	BNNet
Alunite	0.1304	0.1198	0.1201	0.1197	**0.0992**	0.1093
Andradit	0.0992	0.1142	0.1066	**0.911**	0.1639	0.0924
Buddingtonite	0.1108	0.1293	**0.1003**	0.1097	0.1687	**0.1003**
Dumortierite	0.1085	0.1273	0.1131	0.1092	0.1893	**0.0961**
Kaolinite-1	0.0826	0.1003	0.0819	**0.0799**	0.0804	0.0828
Kaolinite-2	0.0813	0.0981	0.0794	0.0732	0.0792	**0.0700**
Muscovite	**0.0937**	0.0982	0.1079	0.1121	0.1080	0.1086
Montmorillonite	0.0645	0.0597	0.0616	0.0652	0.0651	**0.0501**
Nontronite	0.1294	0.1284	0.1254	**0.1071**	0.1437	0.1303
Pyrope	0.0806	0.0887	0.0825	0.0833	0.0803	**0.0796**
Sphene	0.0577	0.0738	0.0638	0.0611	**0.0532**	0.0563
Chalcedony	0.1390	**0.1291**	0.1396	0.1297	0.1496	0.1399
Average SAD	0.0981	0.1059	0.0991	0.0932	0.1070	**0.0901**
RMSE	0.1021	0.1132	0.0872	0.0721	0.1418	**0.0572**

References

[1] M. Zhao, M. Wang, J. Chen, and S. Rahardja, "Hyperspectral unmixing via deep autoencoder networks for a generalized linear-mixture/nonlinear-fluctuation model," *arXiv preprint arXiv:1904.13017*, 2019.

[2] Q. Jin, Y. Ma, F. Fan, J. Huang, X. Mei, and J. Ma, "Adversarial autoencoder network for hyperspectral unmixing," *IEEE Transactions on Neural Networks and Learning Systems*, 2021.