

endmember extraction algorithms, SVDSS and ModPPI. The unmixing results using PPI and SVDSS are quite consistent and related to the fact that we used simulated noise free imagery. We expect more differences with more realistic simulated data.

SVDSS was the best in extracting the four endmembers present in the simulated data but requires prior knowledge of the number of endmembers. However, ModPPI was capable of extracting all component signatures, and it was able to determine the number of endmember from the data. Work is still needed on an approach to select the threshold to determine the number of endmembers in ModPPI.

7. ACKNOWLEDGEMENTS

This material is based on research sponsored by Air Force Research Laboratory (AFRL) under agreement number FA9453-21-2-0064. The U.S. Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation thereon. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of Air Force Research Laboratory (AFRL) and or the U.S. Government.

8. REFERENCES

- [1] Maher Aldeghlawi, Mohammed Q Alkhatib, and Miguel Velez-Reyes. Evaluating column subset selection methods for endmember extraction in hyperspectral unmixing. In *Proceedings of SPIE: Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imagery XXVI*, volume 11392, pages 275–285. SPIE, 2020.
- [2] David A Bennett, Jeff A Dank, David W Tyler, Michael Gartley, and David Allen. Ssa modeling and simulation with dirsig. In *Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference, Maui, HI, USA*, pages 9–12, 2014.
- [3] José M Bioucas-Dias, Antonio Plaza, Nicolas Dobigeon, Mario Parente, Qian Du, Paul Gader, and Jocelyn Chanussot. Hyperspectral unmixing overview: Geometrical, statistical, and sparse regression-based approaches. *IEEE journal of selected topics in applied earth observations and remote sensing*, 5(2):354–379, 2012.
- [4] Joseph W Boardman, Fred A Kruse, and Robert O Green. Mapping target signatures via partial unmixing of aviris data. In *Summaries of the fifth annual JPL airborne earth science workshop. Volume 1: AVIRIS workshop*, 1995.
- [5] Mary E Broadbent, Martin Brown, Kevin Penner, Ilse Ipsen, and Rizwana Rehman. Subset selection algorithms: Randomized vs. deterministic. *SIAM undergraduate research online*, 3(01), 2010.
- [6] Ana C Chavez-Lopez and Miguel Velez-Reyes. Unmixing analysis of close-range hyperspectral images. In *IGARSS 2023-2023 IEEE International Geoscience and Remote Sensing Symposium*, pages 7543–7546. IEEE, 2023.
- [7] Gene Golub, Virginia C Klema, and Gilbert W Stewart. *Rank degeneracy and least squares problems*. Stanford University, 1976.
- [8] Adam A Goodenough and Scott D Brown. DIRSIG 5: core design and implementation. In *Proceedings of SPIE: Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XVIII*, volume 8390, pages 124–132. SPIE, 2012.
- [9] Nathalie Gorretta and Cécile Gomez. *Spectral–Spatial Unmixing Approaches in Hyperspectral VNIR/SWIR Imaging*, volume 30. Elsevier, 2016.
- [10] Ana C Chavez Lopez, Manuel M Goetz Mora, Maria C Torres-Madroño, and Miguel Velez-Reyes. Using hyperspectral unmixing for the analysis of very high spatial resolution hyperspectral imagery. In *Proceedings of SPIE: Algorithms, Technologies, and Applications for Multispectral and Hyperspectral Imaging XXIX*, volume 12519, pages 277–284. SPIE, 2023.
- [11] Yaroslav Shitov. Column subset selection is np-complete. *Linear Algebra and its Applications*, 610:52–58, 2021.
- [12] Miguel Velez-Reyes and Maher Aldeghlawi. Using a column subset selection method for endmember extraction in hyperspectral unmixing. In *Proceedings of SPIE: Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XXIV*, volume 10644, pages 83–89. SPIE, 2018.