Joint Unmixing And Demosaicing Methods For Snapshot Spectral Images

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This work was partly funded by the Région Hauts-de-France. Experiments presented in this work were carried out using the CALCULCO computing platform, supported by SCoSI/ULCO.

Snapshot Spectral Cameras

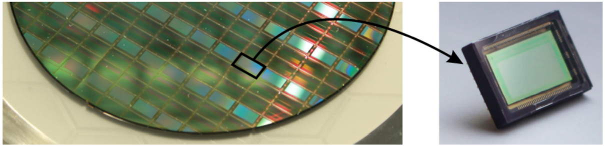


Figure: Wafer including CMOS image sensors with integrated filter mosaics (left) and a packaged sensor (right). (Source Geelen et al.)

Figure: The SnapShot SWIR camera from IMEC using a mosaic pattern of 16 SWIR filters.

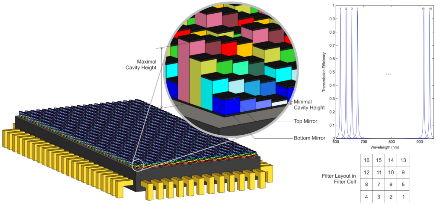
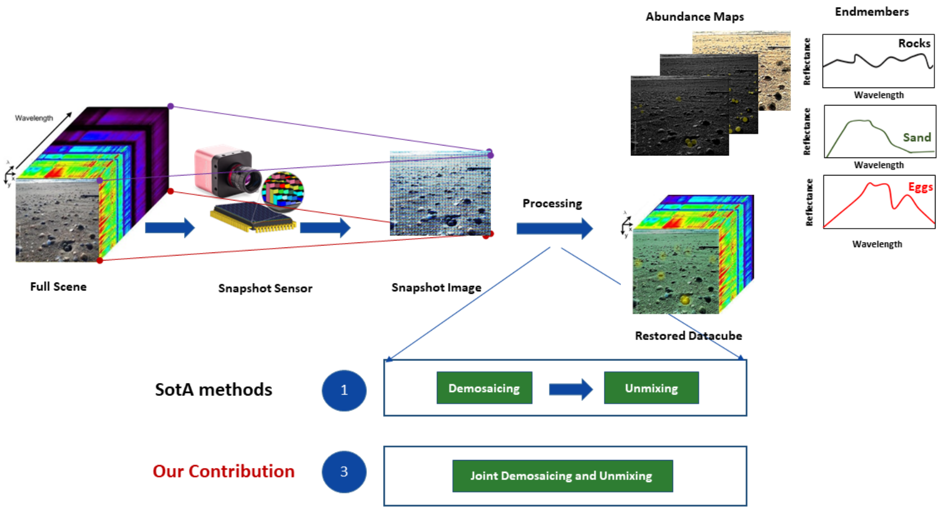


Figure: SSI cameras associate each spatial pixel with a specific spectral band.

Processing the SSI Image



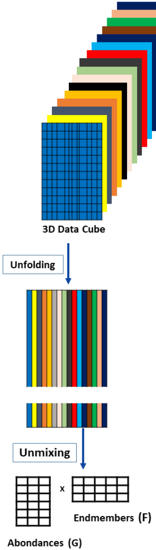
Work Motives

- Low rank matrix completion has been used for demosaicing by Tsagkatakis et al.
- Performing classification after demosaicing provides a poor classification performance (Tsagkatakis et al.)
- For another application, **joint** low-rank matrix completion and factorization far more accurate than a two-stage approach (Dorffer et al.).
- Weighted Non-negative Matrix Factorization (WNMF) is used to solve the joint demosaicing and unmixing problem, i.e.,

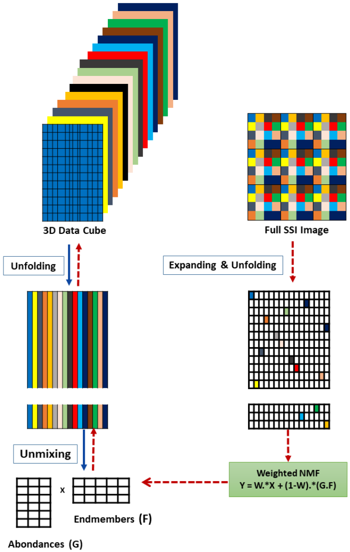
$$W \circ X \approx W \circ (G \cdot F) \tag{1}$$

- Can be solved, e.g., using Expectation Maximization WNMF framework on the entire image.

Naive approach for Joint Demosacing and Unmxing



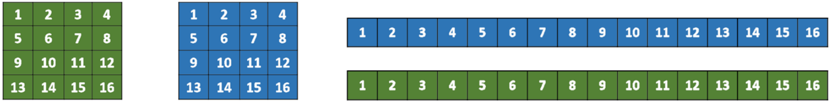
Naive approach for Joint Demosacing and Unmxing



Assumptions required for the proposed method (1/2)

Assumption 1 (Pure Patch Assumption)

For each endmember, there exists at least one sensor “patch” where only this endmember is present.

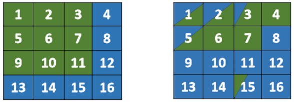


Pure Patch of Grass **Pure Patch of Water** **The Spectra**

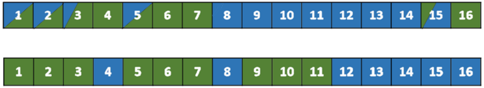
Assumptions required for the proposed method (1/2)

Assumption 2

In the patches where several endmembers are present, their abundances significantly vary over each patch.



Grass and water abundancies vary



Wavelength-dependent mixture of endmembers

Assumptions required for the proposed method (1/2)

Assumption 3

In each pixel, the mixture of the endmembers is expected to be linear.

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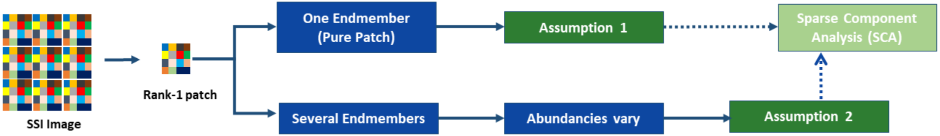
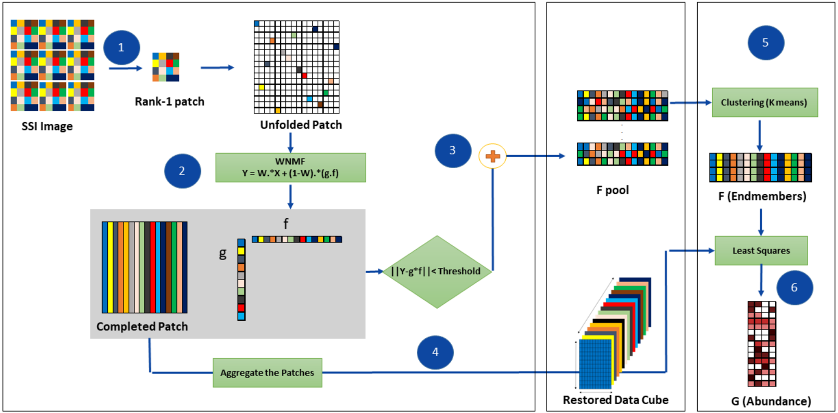


Completion Based Approach, K-means Patch-based Weighted Non-negative Matrix Factorization (KPWNMF)



Experiments

- To assess the performance of the proposed method, we conduct experiments on SSI simulations derived from synthetic images and the CAVE dataset.
- We assume that the hyperspectral imagery is acquired using a SSI camera system, equipped with 5×5 and 4×4 spectral filter patterns.
- Reconstruction quality is measured in terms of Peak Signal-to-Noise Ratio (PSNR, in dB) while the unmixing enhancement is measured using Signal-to-Interference Ratio (SIR, in dB), Mixing Error Ration (MER, in dB) and Spectral Angel Mapper (SAM)

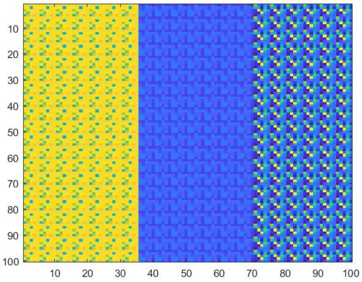


Figure: Simple Image

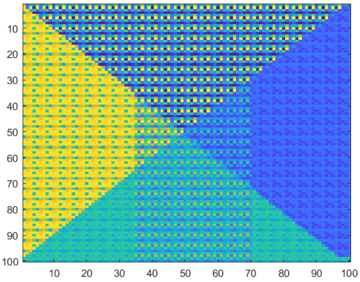


Figure: Complex Image

Results for KPWNMF (1/2)

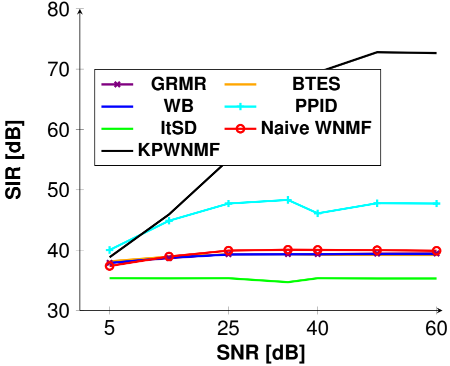


Figure: Mean SIR obtained for real and ideal filters in patches of size 4 $\times$ 4 and 5 $\times$ 5 – relative to input SNR.

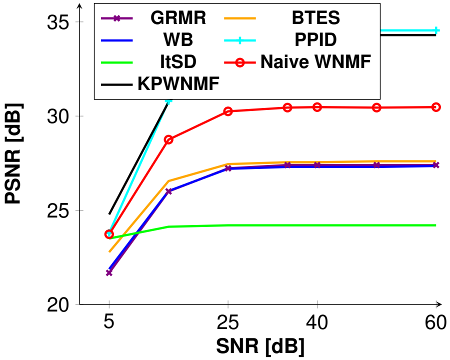


Figure: Mean PSNR obtained for real and ideal filters in patches of size 4 $\times$ 4 and 5 $\times$ 5 – relative to input SNR.

Results for KPWNMF (2/2)

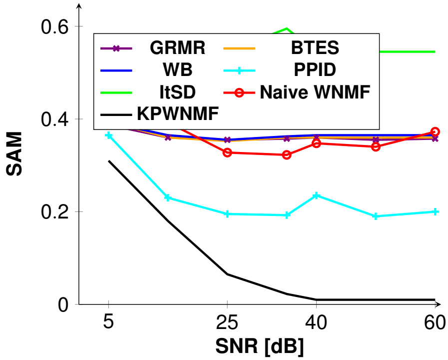


Figure: Mean SAM obtained for real and ideal filters in patches of size 4 × 4 and 5 × 5 – relative to input SNR.

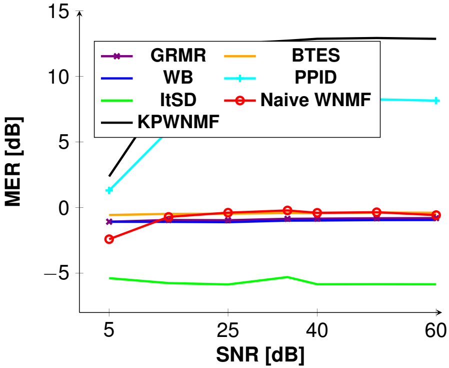


Figure: Mean MER obtained for real and ideal filters in patches of size 4 × 4 and 5 × 5 – relative to input SNR.

Results for KPWNMF (2/2)

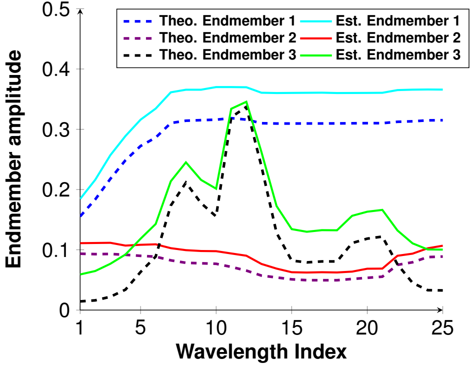


Figure: KPWNMF estimated spectra for complex image

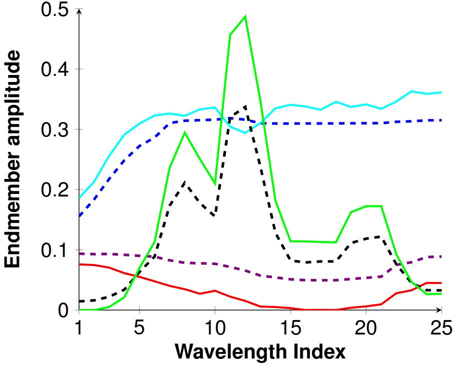
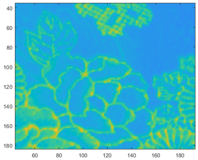
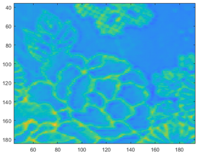


Figure: PPID estimated spectra for complex image

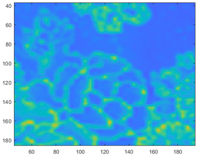
Results on CAVE dataset



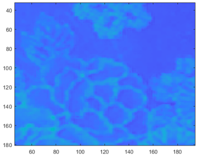
(a) Ground truth



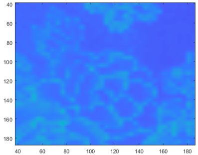
(b) KPWNMF (PSNR=37.7dB)



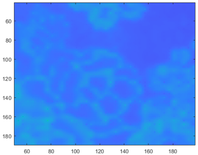
(c) PPID (PSNR=37.1dB)



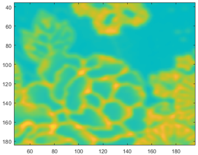
(d) GRMR (PSNR=35.3dB)



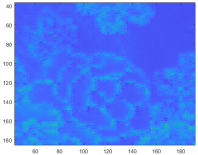
(e) WB (PSNR=35.0dB)



(f) BTES (PSNR=34.7dB)



(g) ItSD (PSNR=30.2dB)



(h) Naive WNMF (PSNR=35.1dB)

Figure: Demosaiced images obtained with KPWNMF and SotA methods for the 4×4 patch, and PSNRs averaged over all the images.

Conclusion and Future Work

Conclusion

- KPWNMF has a slightly better demosaicing performance and a much higher unmixing enhancement than 2-stage approaches.

Future work

- Test the performance on **real SSI data**
- Take into account endmember spectral variability
- Take into account Fabry-Perot filter variability