A Practical Pan-Sharpening Method with Wavelet Transform and Sparse Representation

Yu Liu and Zengfu wang
(university of science and technology of china)

Jaswanth Kumar (MT2022051)

Introduction

- The pan-sharpening technique, which aims at producing a HRM image by fusing a LRM image and a HRP image, has become an effective pre-processing technique in many remote sensing applications.
- Pan Sharpening methods
    - CS - based methods
    - MRA - based methods
    - DM - based methods
    - DNN - based methods

Wavelet Transform :

- The low-frequency components are merged via SR with the dictionary simply learned from natural images, which makes the method more practical.

Sparse Representation(SR):

- SR assumes that natural signal can be approximated by a sparse linear combination of atoms with respect to a dictionary, i.e., $x \approx D*\alpha$

Fusion Scheme:

1. Resample and IHS transform
2. Wavelet transform (WT)
3. Fusion of high-frequency components
4. Fusion of low-frequency components
5. Inverse WT and inverse IHS transform

1. Resample and IHS transform :

Resample the LRM image to the same resolution with the HRP image and apply IHS transform to the resampled version to get its intensity component denoted as INT

2. Wavelet Transform :

Apply WT to HRP and INT to obtain their low-frequency components LP and LI, and high-frequency components HP and HI, respectively.

3. Fusion of high-frequency components

The high-frequency components are fused based on the wavelet energy which is defined as follows

$$HF(i,j)=\begin{cases} HP(i,j), & E(w_P(i,j)) > E(w_I(i,j)) \\ HI(i,j), & otherwise \end{cases}.$$

4. Fusion of low Frequency Component :

The low frequency components are merged together

5. Inverse WT and inverse IHS transform :

Apply inverse wavelet transform to HF and LF to get the fused intensity component, and the final HRM image can be obtained by performing inverse IHS transform.

Dataset

- They used WorldView-2 data to evaluate the effectiveness of the proposed method.
- WorldView-2 is a new high-resolution satellite which provides 8-band multispectral images at 1.84-m resolution and panchromatic images at 0.46- m resolution.
- The dataset contains 23 pairs of LRM and HRP images covering the area of urban, seaside, bridge, etc.Without loss of generality, we consider a pansharpening case only with three spectral bands: Red (R), Green (G) and Blue (B)

Fusion results of the urban images by different methods

PCA

IHS

AIHS

IHS-WV

IHS-SR

IHS-WV-SR

Observations

- By visually comparing the six results, we can see that the results of PCA and IHS methods suffer severe spectral distortion and the situation becomes a little better in AIHS result.
- The IHS-WV, IHS-SR, and IHS-WV-SR methods preserve spectral information well.
- By comparing, we can find that the spatial information of the IHS-WV-SR is more accurate than that of the IHS-SR method, especially in the strong edge areas.

QUANTITATIVE INDEXES OF THE FUSION RESULTS

Indexes	*PCA*	*IHS*	*AIHS*	*IHS-WV*	*IHS-SR*	*Proposed*
SAM	2.1613	1.9119	1.6432	1.6261	1.6045	**1.5931**
ERGAS	8.5942	3.8482	3.5088	3.5763	**2.0687**	2.5676
UIQI-R	0.7790	0.9103	0.9255	0.8744	0.9335	**0.9417**
UIQI-G	0.7682	0.9186	0.9172	0.8617	0.9385	**0.9432**
UIQI-B	0.7515	0.9124	0.9072	0.8488	0.9314	**0.9366**
D_λ	0.1003	0.0302	0.0269	0.0109	**0.0096**	0.0203
D_s	0.1155	0.0505	0.0315	0.1279	0.0459	**0.0159**
QNR	0.7958	0.9208	0.9424	0.8626	0.9449	**0.9641**

Evaluation Indexes

- Spectral Angle Mapper(SAP)
- ERGAS (Enhanced Spatial-Resolution by Generalized Approach to Imaging Spectrometer)
- Universal Image Quality Index (UIQI)
- Quality with No Reference (QNR):
  - Spectral Distortion Index (Dλ)
  - Spatial Distortion Index (Ds)

Conclusion and Future Work

- This paper proposes a new pan-sharpening method with sparse representation under the framework of wavelet transform. In our method, the low-frequency components of wavelet are fused based on sparse representation with the dictionary.

- Future work include extension to more bands,adaptability to different Sensors,handling noisy images.