
2021.11.13

Reporter: Jiang He
Supervisor: Qiangqiang Yuan
Outline

01 Background
02 Method
03 Experiment
04 Summary
Hyperspectral images are of great significance!
Background

- Spectral Super-resolution

Rich Spectral information
Low Spatial Resolution
High Acquisition Cost

More Spatial Detail
Low Spectral Resolution

High Spatial Resolution
Background

Spectral Super-resolution History

- **2014**
  - Nguyen, et al.

- **2015**
  - Kelly, et al.
  - Arad, et al.

- **2016**
  - Jia, et al.
  - Wu, et al.
  - Galliani, et al.
  - Rangnekar, et al.
  - Can, et al.
  - Xiong, et al.

- **2017**
  - Shallow ResNet
  - Dense Unet
  - A+
  - Sparse Recovery
  - Arad, et al.
  - Jia, et al.
  - Wu, et al.
  - Galliani, et al.
  - Rangnekar, et al.
  - Can, et al.
  - Xiong, et al.

- **2018**
  - Not consistent with imaging in practice!

- **2019**
  - Kelly, et al.
  - Shi, et al.
  - Nie, et al.
  - Fu, et al.

- **2020**
  - Yi, et al.
  - Zhang, et al.
  - Mei, et al.
  - Akhtar et al.
  - Li, et al.

Joint Spatial and spectral SR
Background

- Generalized Spectral Super-resolution

Diagram showing the process of super-resolution with various datasets such as Sentinel-2, WorldView-2, Landsat 1-5, GF, Landsat 6-8, QuickBird, PansSR, FusSR, and Desired HSI.
Outline

01 Background
02 Method
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Method

- **Degradation Model**

\[
M_H = X\Phi_1 \\
M_L = DX\Phi_2
\]

- **Model Formulation**

\[
\hat{X} = \arg\min_X \frac{1}{2} \|M_H - X\Phi_1\|^2 + \frac{1}{2} \|M_L - DX\Phi_2\|^2 + \lambda \mathcal{R}(X)
\]

\[
\begin{align*}
\hat{X}_{k+1} &= (1 - \epsilon\mu)X_k - \epsilon X_k\Phi_1\Phi_1^T - \epsilon D^TX_k\Phi_2\Phi_2^T + \epsilon M_H\Phi_1^T + \epsilon D^TM_L\Phi_2^T + \epsilon\mu Z_k \\
\hat{Z}_{k+1} &= \text{Prox}(X_{k+1}) = \arg\min_Z \|Z - X_{k+1}\|^2 + \frac{\lambda}{\mu} \mathcal{R}(Z)
\end{align*}
\]

- Model Requires Manual intervention
- Deep unrolling
- Inadequate expression of single prior
Method

- Deep unrolling
  - $X_{k+1}$ subproblem

\[
\hat{X}_{k+1} = (1 - \epsilon \mu) X_k - \epsilon X_k \Phi_1 \Phi_1^T - \epsilon D^T DX_k \Phi_2 \Phi_2^T + \epsilon M_H \Phi_1^T + \epsilon D^T M_L \Phi_2^T + \epsilon \mu Z_k
\]

\[
\hat{X}_{k+1} = (1 - \epsilon \mu) X_k + X_{k+1}^{\uparrow} + M_{k+1}^{\uparrow} + \epsilon \mu Z_k
\]

\[
X_{k+1}^{\uparrow} = -\epsilon X_k \Phi_1 \Phi_1^T - \epsilon D^T DX_k \Phi_2 \Phi_2^T
\]

\[
M_{k+1}^{\uparrow} = \epsilon M_H \Phi_1^T + \epsilon D^T M_L \Phi_2^T
\]
Method

- Deep unrolling
- X subproblem

$$\hat{X}_{k+1} = (1 - \epsilon \mu) X_k + X_{k+1}^{\downarrow \uparrow} + M_{k+1}^{\uparrow} + \epsilon \mu Z_k$$

$$X_{k+1}^{\downarrow \uparrow} = -\epsilon X_k \Phi_1 \Phi_1^T - \epsilon D^T DX_k \Phi_2 \Phi_2^T$$

$$M_{k+1}^{\uparrow} = \epsilon M_H \Phi_1^T + \epsilon D^T M_L \Phi_2^T$$
Method

- **Deep unrolling**
  - Z subproblem

\[
\hat{Z}_{k+1} = \text{Prox}(X_{k+1}) = \arg\min_{Z} \|Z - X_{k+1}\|_2^2 + \frac{\lambda}{\mu} \mathcal{R}(Z)
\]

\[
\hat{Z}_k = \text{Prox}(X_k) = \arg\min_{Z} \frac{\mu}{\lambda} \|Z - X_k\|_2^2 + \mathcal{R}(Z)
\]
\[
= \arg\min_{Z} \frac{1}{2(\sqrt{\lambda/2\mu})^2} \|Z - X_k\|_2^2 + \mathcal{R}(Z)
\]

\[
\hat{Z}_k = \text{Prox}(X_k) = \text{Denoiser}(X_k) = \text{ResNet}(X_k)
\]
Method

- Deep unrolling
  - Cross-Dimensional Channel Parameter Self-learning

More accurate weight extraction  ➔  Faster computational speed

Diagram: Feature_in → Conv2d → Reshape → ... → Feature_out

- More accurate weight extraction
- Faster computational speed
Method

Physical Optimization-based Spectral Super-resolution Network (PoNet)

- Cross-Depth Feature Fusion (CFF)

\[
F_{k-1}^C = \text{Concat}(X_0, X_1, X_2, \cdots X_{k-1})
\]
\[
X_{k}^{In} = \text{ReLU}(W_{k-1}^F \ast F_{k-1}^C + b_{k-1}^F)
\]

Deep and Shallow features
Outline

01 Background
02 Method
03 Experiment
04 Summary
Datasets
- RgB2CAVE

HSIs:
- 400-700nm
- 31 bands

Red:
- 400-550nm
- HR

Green:
- 450-700nm
- LR

Blue:
- 550-700nm
- HR
Experiment

- **Datasets**
  - **Sen2CHRIS**
  - **Xiongan dataset**

  **HSIs:**
  - 406-1003nm
  - 62 bands

  **HR MSIs:**
  - R G B NIR
  - 4 bands

  **LR MSIs:**
  - Red Edge1 2 3
  - 3 bands

- **Chikusei dataset**
Datasets
- RgB2CASI

2018 IGARSS Data Fusion Contest

**HSIs:**
- 380-1050nm
- 48 bands

**RGB:**
- 380-1050nm
- LR Green
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<td></td>
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<td>Bili</td>
<td>Conv</td>
<td>Max</td>
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Experiment

- Influence of Sampling Operator

(a) SAM

(b) mSSIM

(c) ERGAS
**RGB2CAVE**

- **Quantitative results**

<table>
<thead>
<tr>
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<th>SSR</th>
<th>FusSR</th>
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<tbody>
<tr>
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<tr>
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Experiment

- **RgB2CAVE**
  - SSR
  - FusSR

Graphs showing data for different wavelengths (440 nm, 490 nm, 540 nm, 590 nm, 640 nm, 690 nm) for various models including DRLnet, ConvNet, HESNet+, and R-Net.
## Experiment

### Sen2CHRIS

#### Quantitative results

<table>
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<th>SSR</th>
<th>Models</th>
<th>Xiongan</th>
<th>Sub-dataset</th>
<th>Washington DC Mall</th>
<th>Chikusei</th>
<th>SAM</th>
<th>SAM</th>
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### FusSR

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Experiment

- Sen2CHRIS
  - SSR
  - FusSR

- DirectNet
- GeoNet
- HSCNN
- HRNet
- PaNet

Color maps for different wavelengths (561 nm, 641 nm, 703 nm, 755 nm, 833 nm, 905 nm, 997 nm).
- **RgB2CASI**
  - Quantitative results

<table>
<thead>
<tr>
<th></th>
<th>SSR</th>
<th>FusSR</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>CC mPSNR mSSIM SAM</td>
<td>CC mPSNR mSSIM SAM ERGAS</td>
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<td>DenseU</td>
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<tr>
<td>CanNet</td>
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<tr>
<td>PoNet</td>
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<td><strong>0.8479</strong> 30.5309 <strong>0.8683</strong> <strong>12.5997</strong> 9.2775</td>
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</table>
**Experiment**

- **RgB2CASI**
  - **SSR**

- **FusSR**
## Experiment

- **PansSR**
  - Quantitative results

<table>
<thead>
<tr>
<th>Images</th>
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Experiment

- **PansSR**
  - Input data

Up-sampled MSI

PAN
Experiment

- PansSR
  - Results
Experiment

- PansSR
  - Ground Truth

(a): Band 47 of ground truth
(b): Band 48 of ground truth
(c): Band 49 of ground truth
(d): Band 50 of ground truth
### Ablation Study

<table>
<thead>
<tr>
<th>Models</th>
<th>Optimization Stage</th>
<th>Down and Up</th>
<th>CDCA</th>
<th>CDFF</th>
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<th>SAM</th>
<th>ERGAS</th>
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This paper defines the **generalized spectral super-resolution** for arbitrary multispectral images including data with multiple spatial resolutions, namely, SSR, FusSR, and PansSR.

Unfolding optimization algorithm considering physical degradation to deep learning gives CNN the important **physical interpretability**, which provides a great help to recover hyperspectral information. Besides, to learn parameters channel-to-channel adaptively, as well as boost computation, **cross-dimensional channel attention** is proposed. We also employed both **deep and shallow features** to perform better spectral enhancement as well as good spatial fidelity.

Datasets involving from natural images to multi-scale remote sensing images, namely, RgB2CAVE, Sen2CHRIS, RgB2CASI, and GF2Hyper, to evaluate the method performance in three multispectral acquisitions are built. Quantitative and visual comparisons proved the superiority of the proposed PoNet. Furthermore, sampling operator discussion and ablation study are also shown to verify the effectiveness of each strategy.
Thanks!

Homepage
https://jianghe96.github.io/

Reporter: Jiang He