A low-complexity destriping method for lossless compression of remote-sensing data

Zhaoyi SUN, Yuliang HUANG, Roberto LEONARDUZZI and Jie SUN

Theory Lab, 2012 Laboratory, HUAWEI

Remote Sensing and Stripes

- Remote Sensing techniques are commonly used in many fields.

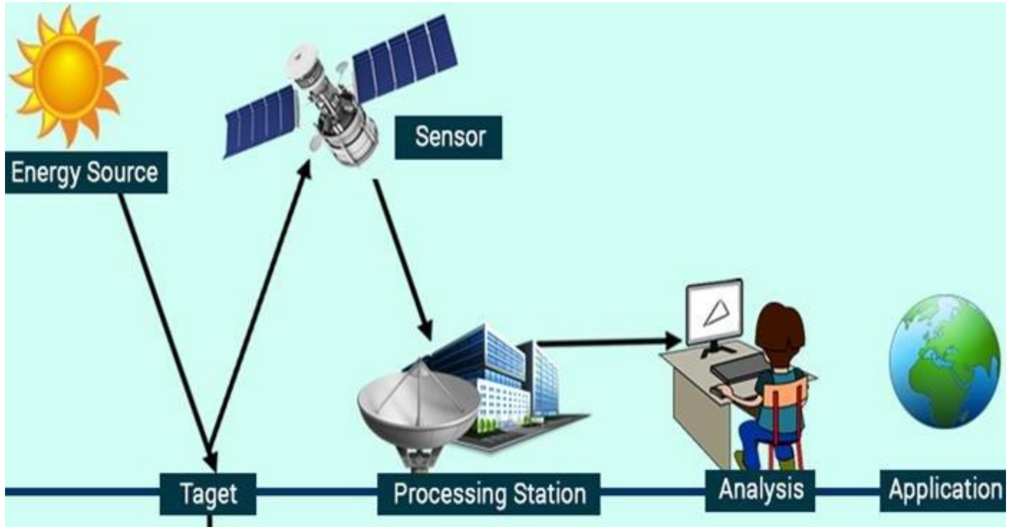


Figure 1. Remote Sensing Process [1]

Figure 2. Application of Remote Sensing

- Vast amounts of data need to be compressed for storage and transmission.

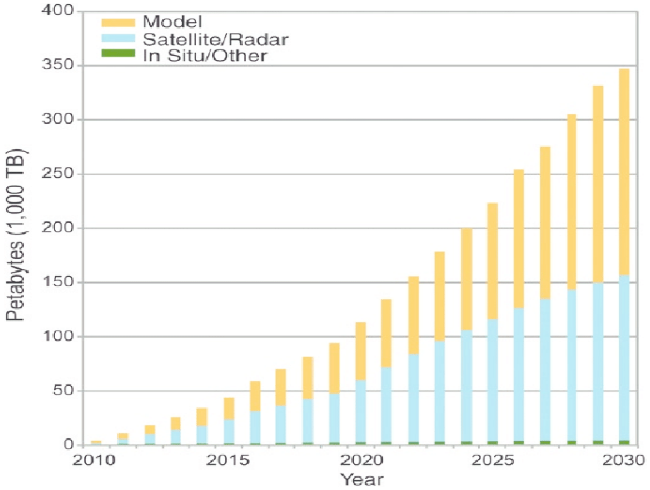


Figure 3. Amount of data related to RS [2]

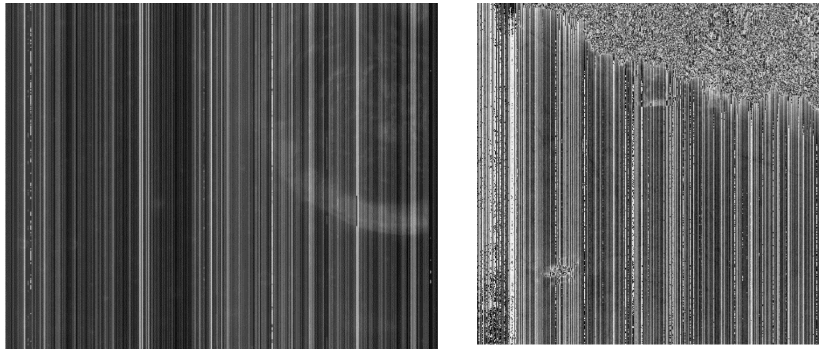


Figure 4. Examples of striping artifacts in remote sensing images. Left: M3-Global; Right: Sentinel-2.

- Concatenating process leads to striping artifacts.
- To reduce entropy, lossless compression algorithms exploit the relation between pixels.
- Striping artifacts make compression difficult since pixel relations are dominated by stripes.

Destriping and Compression

Why Destriping?

An improper modeling will lead to extra entropy during lossless compression:

$$H(P,Q) = H(Q) + D_{KL}(P||Q) \geq H(Q),$$

where Q is the information source and modeled by P, and $D_{KL}(\cdot\,||\,\cdot)$ is the cross entropy. The striping artifacts act like a random perturbation and make modeling difficult.

Literature: Destriping of Remote Sensing images has received considerable attention

- Probabilistic model and MAP framework
- Multiscale method based on wavelet transform
- Varational methods
- Combination of Wavelet transforms and deep networks

Problem: They are not tailored towards lossless compression.

- Large amounts of side information are produced.
- Computationally intensive

Our Contribution: Fast splitting-based compression

- Low complexity: linear on the number of pixels and could be vectorized for acceleration.
- Robustness: use of robust statistics to detect stripes.
- Minimal storage of side information: Only a pair of integers is stored per stripe

Methodology

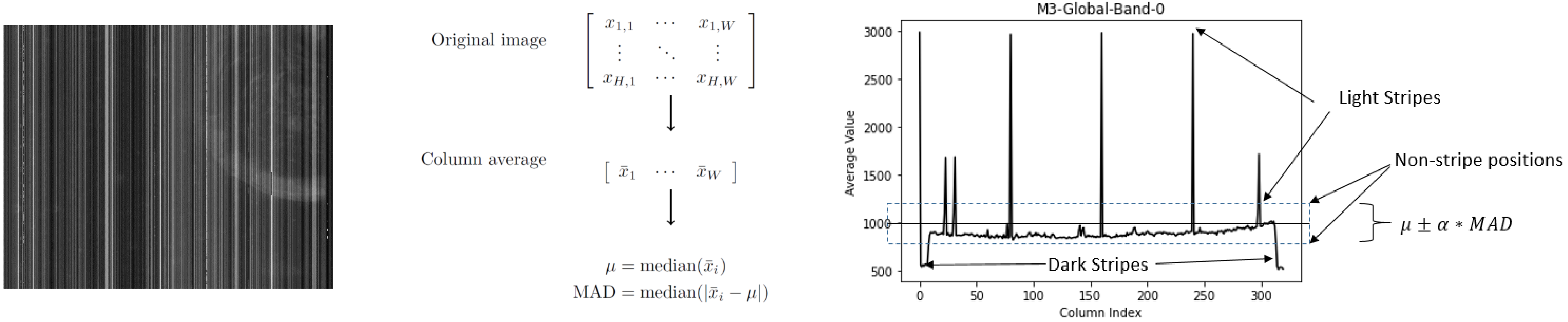


Figure 5: Detecting Procedure: Taking column operations for example. Stripes are detected based on column intensity averages with Median Absolute Deviation.

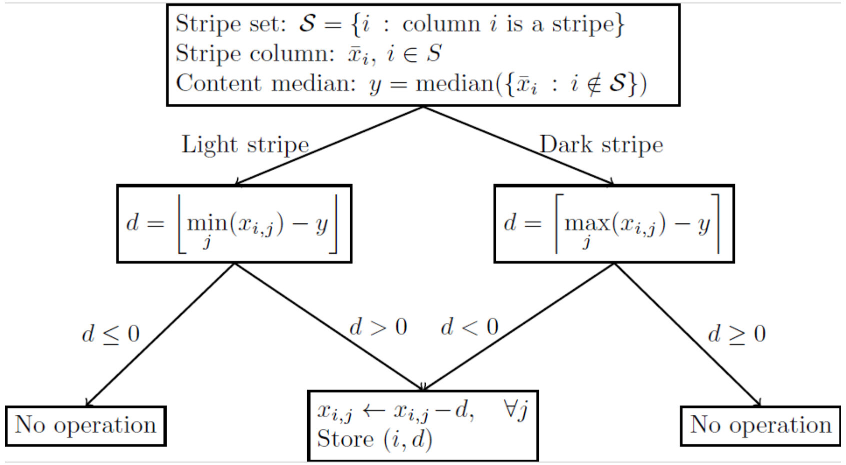


Figure 6: Destriping Procedure

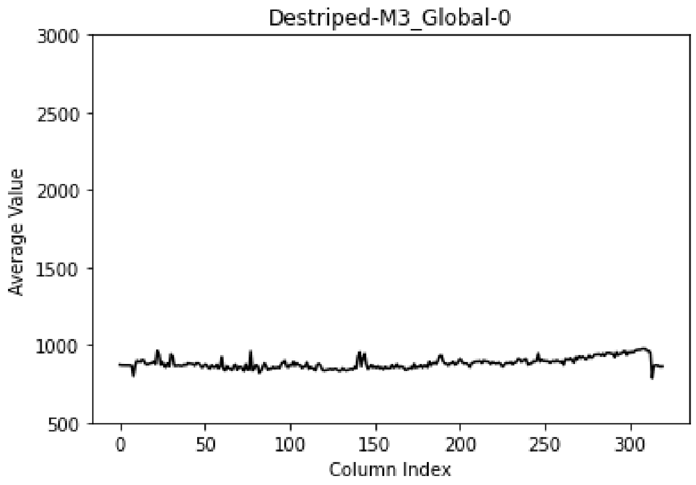


Figure 7: Destriping Results

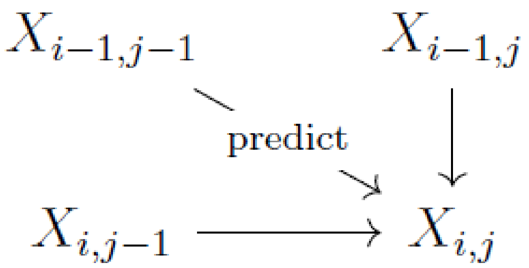
Characterization of Smoothness

To have a measure of the improvements in image quality after destriping, a smoothness index is introduced.
The $L^p - smoothness\ S_p(X)$ of X, a single channel image with size $H \times W$, is defined as follows:

$$S_p(X) := \frac{r(X)}{4096}\left(\frac{1}{N}\sum_{i=1}^{H}\sum_{j=1}^{W}\left(\frac{|X_{i,j}-X_{i,j-1}|+|X_{i,j}-X_{i-1,j}|+|X_{i,j}-X_{i-1,j-1}|}{3}\right)^p\right)^{1/p}$$

, where $N = (H-1)\times(W-1)$ and $r(X) = max_{i,j}\{X_{i,j}\} - min_{i,j}\{X_{i,j}\}$.

In prediction based image compression algorithms, it is typically that the horizontal, vertical and diagonal directions are involved in the prediction phase.



The L_p-smoothness thus provides a relevant indicator for compression-oriented destriping methods. A decrease on it is correlated to compression ratio improvements.

Compression Results

Dataset	PNG CR			JPEG-XL CR			WEBP CR			L^p-smoothness	
	original	destriped	lifted (%)	original	destriped	lifted (%)	original	destriped	lifted (%)	original	destriped
M3 Global	2.10	2.22	5.8	2.93	2.99	2.1	3.19	3.33	4.5	131.53	7.04
M3 Target	2.11	2.52	19.4	2.83	2.92	3.0	4.41	4.67	5.8	160.46	4.07
Modis	4.1	4.7	14.6	8.60	9.40	9.3	8.50	9.40	10.6	0.001	0.001
S2 mag25	2.65	2.93	10.6	4.91	4.97	1.3	5.19	5.37	3.5	975.43	532.87
S2 mag1	4.06	4.23	4.2	5.14	5.22	1.6	5.88	6.08	3.4	35.19	35.18

Table 1: We choose several remote sensing datasets from the internet and present the experiment results under PNG, JPEG-XL and WEBP.

Data	Size(D*H*W)	Number of Stripes	Cost of stripes %
M3 Global	8*512*320	77	0.0176
M3 Target	8*512*640	68	0.0078
Modis	4*370*370	15	0.0082
S2 mag25	10*700*700	1583	0.0970
S2 mag1	10*700*700	3	0.0002

Table 2: Though the cost of side information has been counted in Table 1, we show the it separately to confirm our declaration.

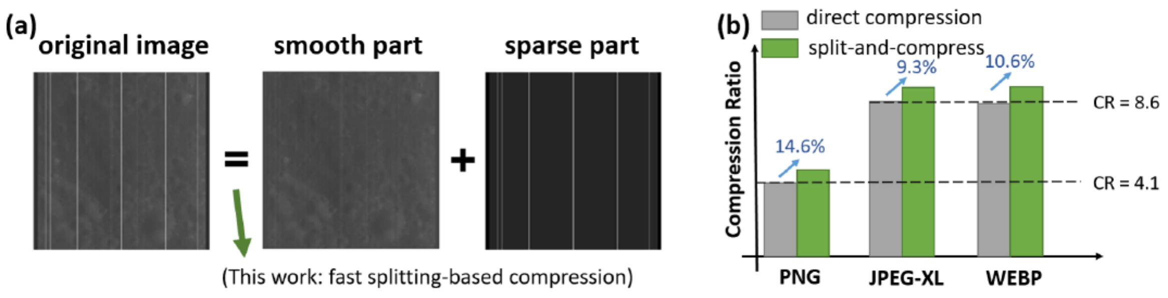


Figure 8: A summary of our idea and results.

References

[1] Singh, Beependra & Chockalingam, Jeganathan & Rathore, Virendra. (2018). Remote Sensing Technology for Monitoring and Modelling Ecological Processes.

[2] Bathiany, Sebastian & Dijkstra, Henk & Crucifix, Michel & Dakos, Vasilis & Brovkin, Victor & Williamson, Mark & Lenton, Timothy & Scheffer, Marten. (2016). Beyond bifurcation: using complex models to understand and predict abrupt climate change. Dynamics and Statistics of the Climate System. 2016. 1-31. 10.1093/climsys/dzw004.

Thank you!