Use Case: Data Correction

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- Special case of co-registration
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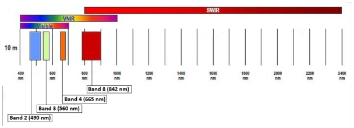
Accessing Data

Introduction

- Download Images from Copernicus Open Access Hub
- The ”GRANULE” folder contains rasters from different bands.
  - Each band contain information about a part of the spectral domain
  - Each of those band have a spatial & radiometric resolution
- More specifically for B04:
  - Central wavelength: 665 nm
  - Spatial resolution: 10m
  - Radiometric resolution: 4095 intensity values



Rasters

Introduction

- Open the raster B04 with Rasterio
- A Raster contains:
  - Matrix grid with 4095 intensities encoded in 16-bit.
  - Metadata about the raster's georeference.
- Georeferencing:
  - Each raster is expressed in a coordinate reference system (CRS)
  - Each raster contain a transformation matrix from the pixel domain to the CRS

```
------Reference Image------
Coordinate Reference System: EPSG:32646
Coordinate Transformation:
| 10.00, 0.00, 199980.00|
| 0.00,-10.00, 2600040.00|
| 0.00, 0.00, 1.00|

------Registered Image------
Coordinate Reference System: EPSG:32645
Coordinate Transformation:
| 10.00, 0.00, 799980.00|
| 0.00,-10.00, 2600040.00|
| 0.00, 0.00, 1.00|
```

Operations on Rasters

Introduction

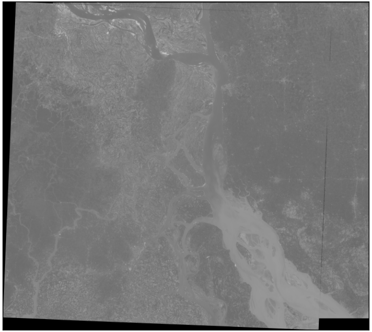


Figure: Rasters projected and Merged in the reference coordinate

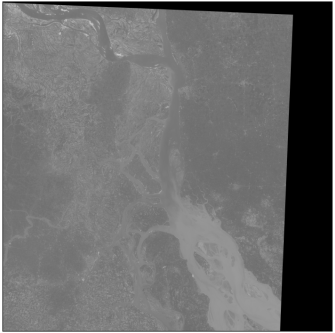


Figure: Registered raster projected to the reference bounding box

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Applying a padding

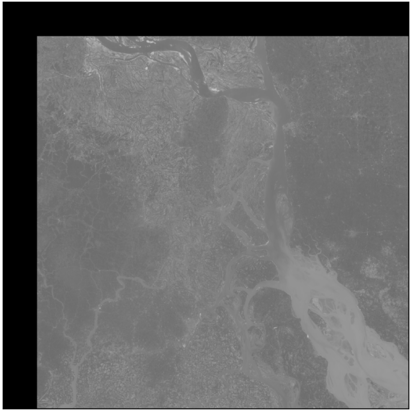
Data preparation

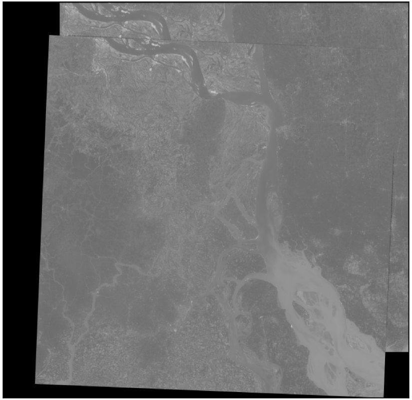
- Open and read file with Rasterio
- Modify the raster's matrix in order to add padding with Numpy
- Do not update the transformation to create a wrong georeferencing
- Write a new padded raster with Rasterio

Applying a padding: Results

Data preparation

- Result after applying a padding of 1000 pixels.

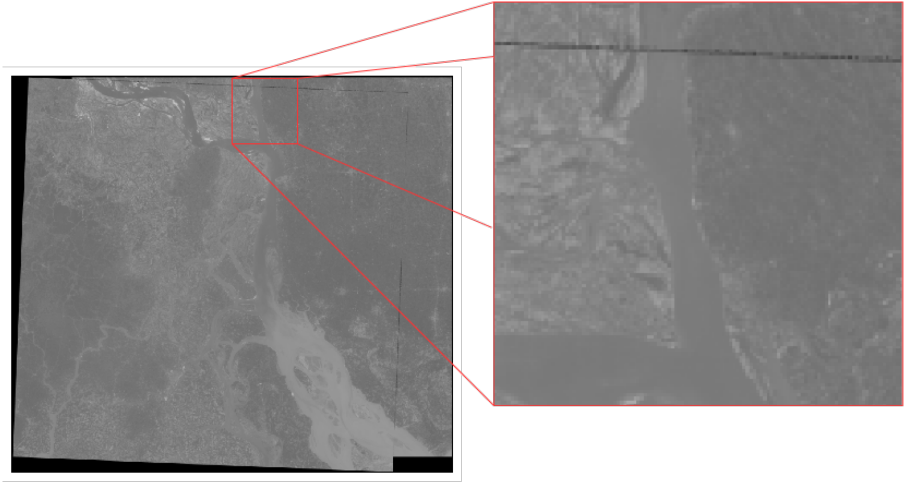




Applying a padding: Results

Data preparation

- Result after applying a padding 30 pixels.



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Preprocessing steps

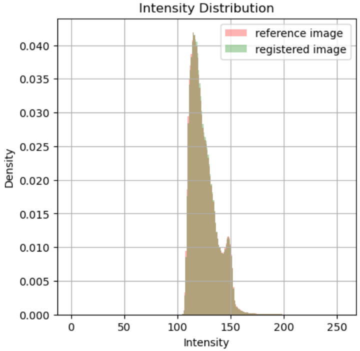
Image co-registration and georeferencing: Choice of methods

- Convert to 8-bit images
  - 12 bit image is not supported in opencv
  - Some algorithm are not optimized with 16-bit images.
  - Memory efficiency and speed
  - Loss of details
- No rescalling of the image
  - Slower, worst computational complexity
  - No loss in details
  - Sufficiently fast with ORB keypoints and descriptors

Preprocessing steps: Histogram

Image co-registration and georeferencing: Choice of methods

- No Histogram Equalization:
  - SIFT, SURF, ORB are invariant in luminance and contrast change [1]
  - Comparable result with or without equalization



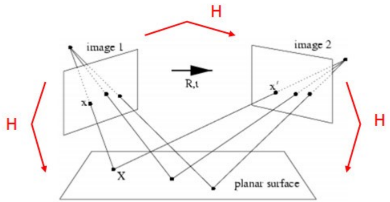
Features detection, description and matching

Image co-registration and georeferencing: Choice of methods

- Feature detection & description: Oriented FAST Rotated BRIEF (ORB) [3] [1] [4]
  - A magitude of 100 times faster than SIFT / SURF.
  - SIFT and ORB show almost similar performances in most situations
- Feature Matching :Brute-Force [2]
  - Faster than FLANN based Matcher when there are 500 features
  - Better matches returned than FLANN based Matcher

Affine transform and homographic transform

- Affine transform describes the relationship between two images, where one image is rotated, shifted, or sheared relative to the other
  - Affine transformation preserves parallel lines and their distance ratio
- Homographic transform describe the relationship between 2 images that share the same planar surface.
  - Homography is used to correct perspective distortion and do not preserve parallel lines



Performance metrics: Root Mean Squared Difference (RMSD)

Let define:

- $I_1(x, y)$ as the intensity of image 1 at the pixel located in (x, y)
- $I_2(x, y)$ as the intensity of image 2 at the pixel located in (x, y)
- $\mathcal{I}$ the set of inliers pixels

Root Mean Squared Difference is defined as:

$$\text{RMSD} \triangleq \sqrt{\sum_{(x,y)\in\mathcal{I}} \Big(I_1(x, y) - I_2(x, y)\Big)^2}$$

Performance metrics: Root Mean Squared Difference (RMSD)

- Pro:
  - Simple and intuitive metric for comparing two images
- Cons:
  - Sensitive to noise / outliers
  - No invariance against consistent changes in brightness and contrast

Performance metrics: Correlation

Let's define

- $I_1(x, y)$ as the intensity of image 1 at the pixel located in (x, y)
- $I_2(x, y)$ as the intensity of image 2 at the pixel located in (x, y)
- $\mathcal{I}$ the set of inliers pixels

Correlation is defined as:

$$\rho_{1,2} \triangleq \frac{\sigma_{1,2}}{\sigma_1 \sigma_2}$$

Where

- σ_1 is standard deviation of image 1
- σ_2 is standard deviation of image 2
- $\sigma_{1,2}$ is the covariance between image 1 and 2

Performance metrics: Correlation

Image co-registration and georeferencing: Choice of methods

$$\rho_{1,2} \triangleq \frac{\sigma_{1,2}}{\sigma_1 \sigma_2}$$

Where

$$\sigma_1^2 = \frac{1}{N-1} \sum_{(x,y)\in\mathcal{I}} \Big(I_1(x,y) - \mu_1\Big)^2$$

$$\sigma_2^2 = \frac{1}{N-1} \sum_{(x,y)\in\mathcal{I}} \Big(I_2(x,y) - \mu_2\Big)^2$$

$$\sigma_{1,2} = \frac{1}{N-1} \sum_{(x,y)\in\mathcal{I}} \Big(I_2(x,y) - \mu_2\Big)\Big(I_1(x,y) - \mu_1\Big)$$

Summary

Image co-registration and georeferencing: Choice of methods

- **Preprocessing:**
  - 8-bit images
  - No rescalling
  - No equalization
- **Feature detection / description & Matching**
  - ORB for feature detection & description
  - Brute Force for matching
  - Affine and Homographic transform
- **Performance metrics**
  - Root mean square difference (RMSD)
  - Correlation

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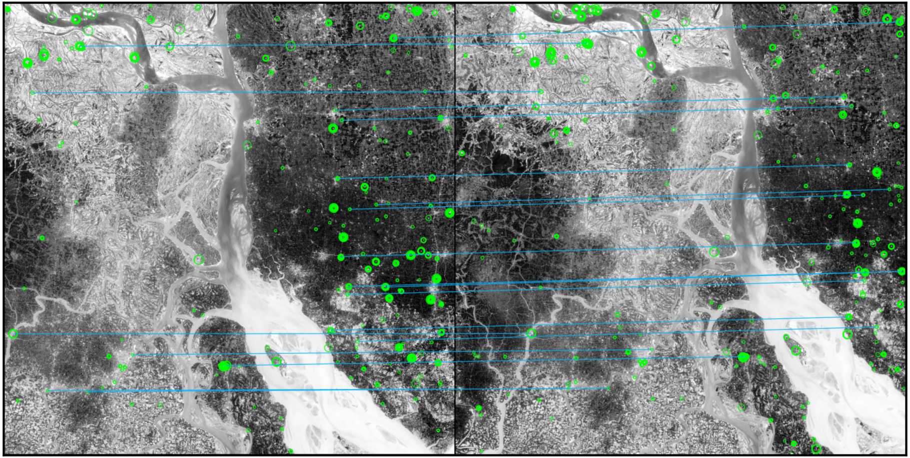
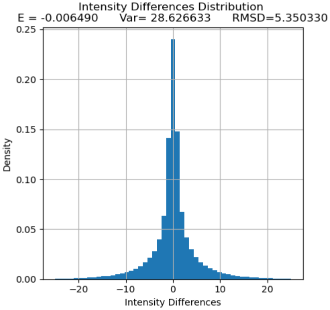
Result obtained after ORB and Brute-Force method

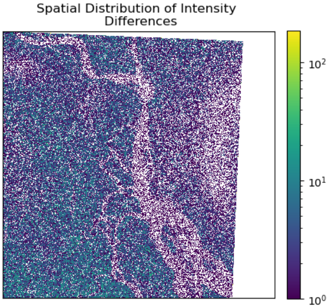
Results & Interpretations

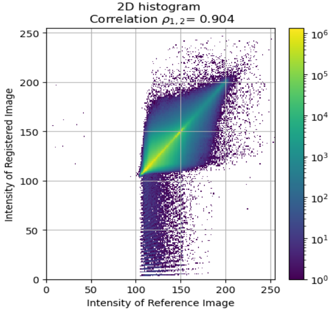


Co-registration with Affine transform: Results

Results & Interpretations

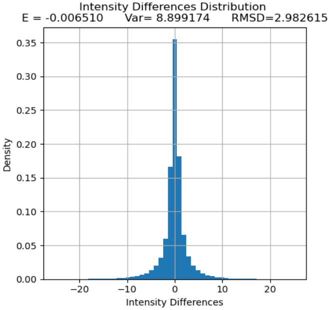


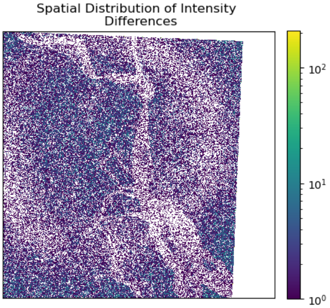


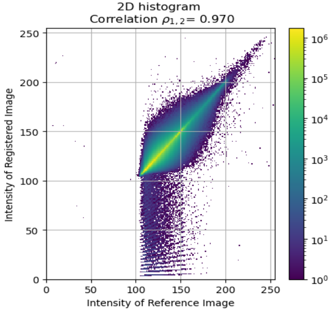


Co-registration with Homographic transform: Results

Results & Interpretations

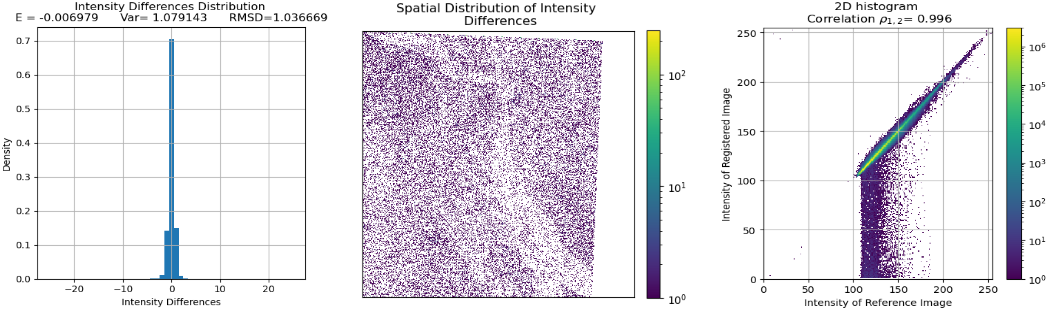






Rasterio reprojection: Results

Results & Interpretations



Summary of the results

Results & Interpretations

- Homographic transform assume that keypoints belongs to a same plane.
- This approximation is not totally true since earth's surface is curved.
- Rasterio reprojection take into account those curves and correct it when changing coordinate reference system.

	ORB (Affine)	ORB (Homography)	Rasterio
Expectation	$-6.49\,10^{-3}$	$6.51\,10^{-3}$	$-6.98\,10^{-3}$
Variance	28.63	8.90	1.08
RMSD	5.35	2.98	1.04
Correlation	0.904	0.970	0.996

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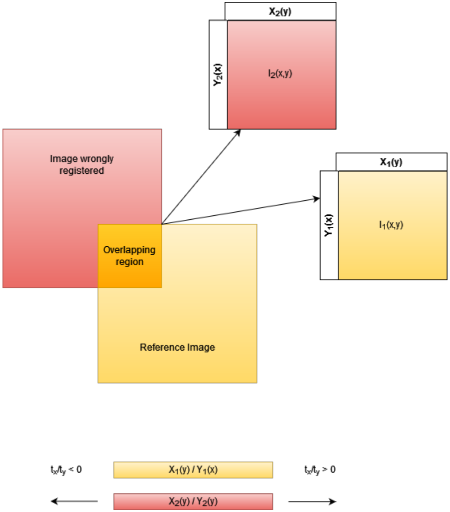
Special case of co-registration

Special case of co-registration



- Let's define an the overlapping region: $I_1(x, y)\; I_2(x, y) \in \mathbb{R}_+^{m,n}$
- Idea: Find the translation (t_x, t_y) that maximize cross-correlation $\rho_{1,2}$ between $(I_1, I_2) \rightarrow 40^2\mathcal{O}(n^2)$
- Idea: Sum over rows and columns and performing cross-correlation on those vectors $\rightarrow 80\mathcal{O}(n)$

Special case of co-registration

- Let define:
  - $X_i(x)$ which is the sum over the columns of $I_i(x, y)$:

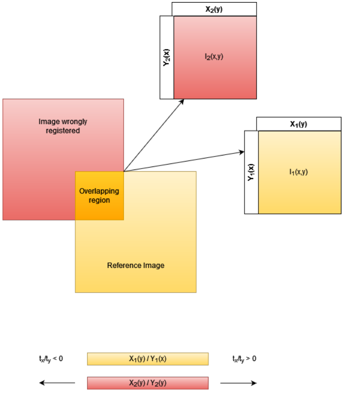
$$X_i(x) \triangleq \sum_y I_i(x, y) \quad i = 1, 2$$

  - μ_{X_i} which is the mean of $X_i(x)$:

$$\mu_{X_i} \triangleq \frac{1}{n} \sum_{x=0}^{n-1} X_i(x) \quad i = 1, 2$$

  - $\sigma^2_{X_i}$ which is the variance of $X_i(x)$

$$\sigma^2_{X_i} \triangleq \frac{1}{n-1} \sum_{x=0}^{n-1} \left(X_i(x) - \mu_{X_i}\right)^2 \quad i = 1, 2$$



Special case of co-registration

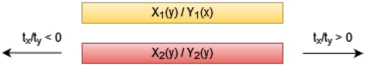
Special case of co-registration

- In order to find the right translation t_x, we want to maximize the cross-correlation:

$$t_x = \underset{t \in [-20,20]}{\arg\max} \frac{\frac{1}{n-1} \sum_x \Big(X_1(x) - \mu_{X_1} \Big) \Big(X_2(x-t) - \mu_{X_2} \Big)}{\sigma_{X_1} \sigma_{X_2}} \tag{1}$$

- In a similar way, we can find the translation t_y:

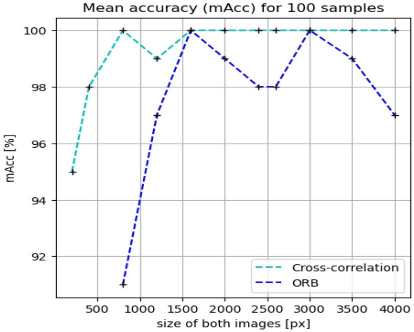
$$t_y = \underset{t \in [-20,20]}{\arg\max} \frac{\frac{1}{m-1} \sum_y \Big(Y_1(y) - \mu_{Y_1} \Big) \Big(Y_2(y-t) - \mu_{Y_2} \Big)}{\sigma_{Y_1} \sigma_{Y_2}} \tag{2}$$

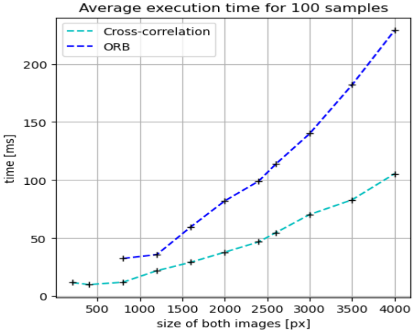


Results

Special case of co-registration

- The proposed method is performed on pairs of subimages from the reference image.
- The proposed method performed better than ORB + affine transformation both on time complexity and mean accuracy.





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Conclusion
Conclusion

- Feature-based method is a correct way to do local registration
- ORB is a result of trade-off between speed and accuracy
- Registration techniques shows limitation in rasters where curvature and elevation are not negligable.
- The choice of the method depend specifically on the problem

Use Case: Data Correction

Thank you for listening!
Any questions?

References

[1] Ebrahim Karami, Siva Prasad, and Mohamed Shehata. *Image Matching Using SIFT, SURF, BRIEF and ORB: Performance Comparison for Distorted Images*. 2017. arXiv: 1710.02726 [cs.CV].

[2] Frazer K. Noble. "Comparison of OpenCV's feature detectors and feature matchers". In: *2016 23rd International Conference on Mechatronics and Machine Vision in Practice (M2VIP)*. 2016, pp. 1–6. DOI: 10.1109/M2VIP.2016.7827292.

[3] Ethan Rublee et al. "ORB: An efficient alternative to SIFT or SURF". In: *2011 International Conference on Computer Vision*. 2011, pp. 2564–2571. DOI: 10.1109/ICCV.2011.6126544.

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[4] Shaharyar Ahmed Khan Tareen and Zahra Saleem. "A comparative analysis of SIFT, SURF, KAZE, AKAZE, ORB, and BRISK". In: *2018 International Conference on Computing, Mathematics and Engineering Technologies (iCoMET)*. 2018, pp. 1–10. DOI: 10.1109/ICOMET.2018.8346440.