GEFOLKI

Instruction manual

Object
Instruction Manual for using GeFolki in order to ensure remote sensing image coregistration
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license and the respective conditions of working

The GeFolki module is distributed under the GPL license.

GeFolki is the subject of two different publications. If you use this code in a publication or scientific work, please quote one of the two publications below.

- In the context of the coregistration of **two remote sensing images of the same nature** (same band of the electromagnetic spectrum: SAR / SAR of the same band, optical / optical in the same channel, etc.), even if the resolutions are different: Images are said to be homogeneous. The publication to be quoted is then:

Aurélien Plyer, Elise Colin-Koeniguer, Flora Weissgerber, "A New Coregistration Algorithm for Recent Applications on Urban SAR Images", Geoscience and Remote Sensing Letters, IEEE , vol.12, no.11, pp. 2198 – 2202, nov 2015

- In the context of the coregistration of **two images of different natures** (SAR / LIDAR, SAR-X / SAR band L, SAR / optical, two different optical bands, etc.), the images are considered to be heterogeneous. The publication to be quoted is then:

Guillaume Brigot, Elise Colin-Koeniguer, Aurélien Plyer, Fabrice Janez, "Adaptation and Evaluation of an Optical Flow Method Applied to Coregistration of Forest Remote Sensing Images", IEEE Journal of Selected Topics in Applied Earth Observations ans Remote Sensing, Volume 9, Issue 7, July 2016

The contents of the instructions

Gefolki is a module allowing carrying out the coregistration of two images of remote sensing.

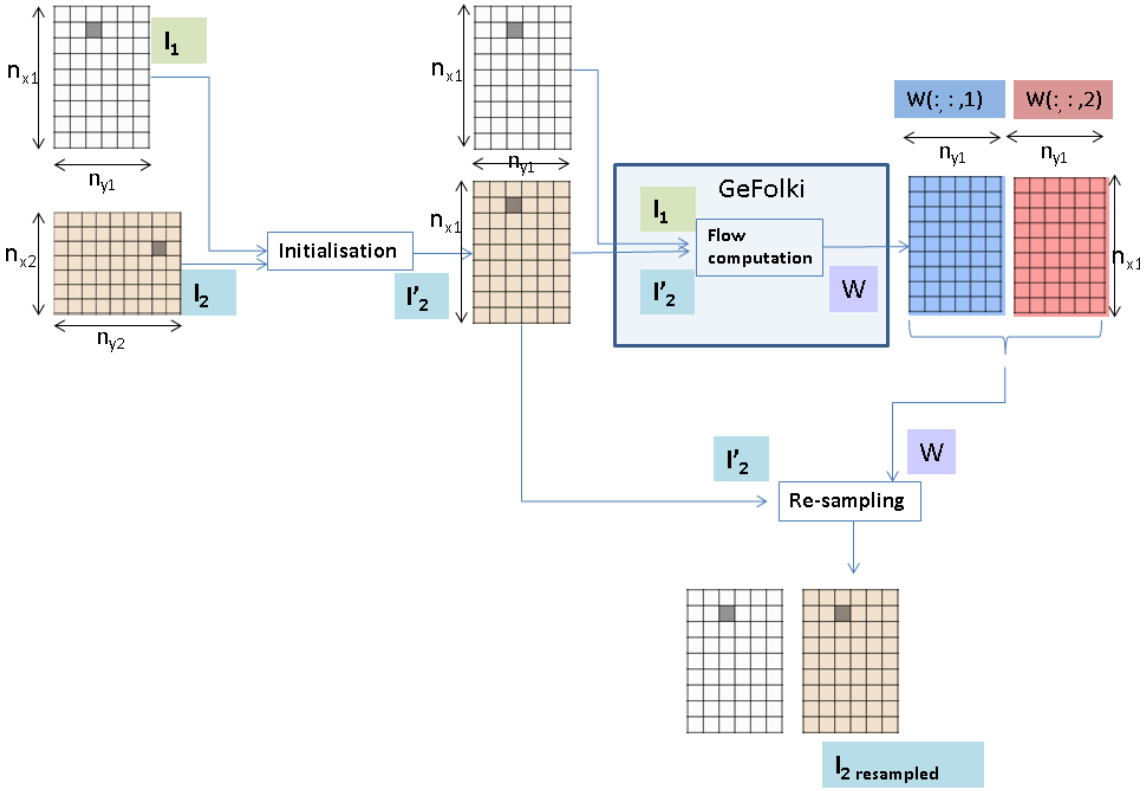
In this manual, a description is given about:

• Various modules to ensure the entire co-registration of two images: initialization, flow calculation (assured by GeFolki) and resampling.

• Recommendations on the choice of the different parameters involved in GeFolki according to the scenario envisaged.

In the most general way, the pixel matching of two images can be decomposed into three steps

1. An initialization step
2. The flow calculation step (GeFolki)
3. A final resampling step



These three steps and their input-outputs are described in the diagram above.

1. The initialization step takes as input the two images of different sizes to be co-registrated. The output is the second slave image transformed into an image of the same size as the master image: n_{x1} x n_{y1}.
2. The flow calculation step is ensured by the code GeFolki.m . This step takes as input two images of the same dimensions. The output W is a three-dimensional matrix corresponding to the flow with size (n_{x1} x n_{y1} x 2).
   - W(:, :,1) corresponds to the component of the flow computed on the horizontal axis.
   - W(:, :,2) corresponds to the component of the flow computed on the vertical axis.
3. The third step consists in the re-sampling of the slave image following the flow matrix previously calculated. This step has two inputs: the image I_2' and the flow matrix W. The output is the resampled image $I_{2resampled}$ that is co-registred to the image I_1.

DESCRIPTION OF THE FIRST STEP : INITIALIZATION

Consider that I1 et I2 are the two images to be registered with respective dimensions (number of rows x number of columns) : (n_{x1} x n_{y1}) et (n_{x2} x n_{y2})

The initialization step consists in putting the images roughly in the same geometry, with pixels of the same size, and the same number of pixels (n_{x1} x n_{y1}).

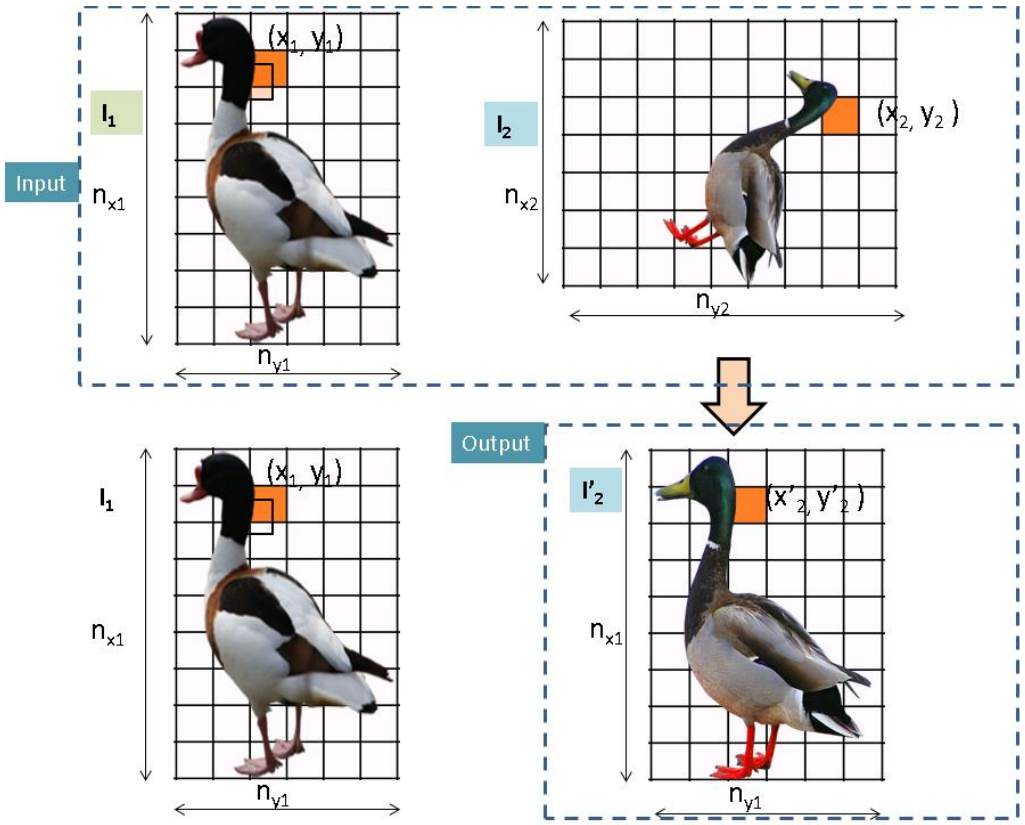


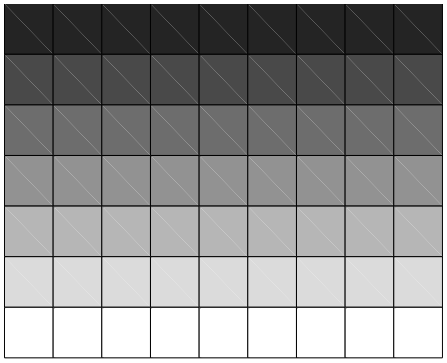
Image I_1 is considered as the master image and image I_2 as the slave image.

The first operation is to apply a matlab command that defines the matrices X and Y where X gives the row number and Y the column number:

```
[Y,X]=meshgrid((1:ny),(1:nx)) ;
```

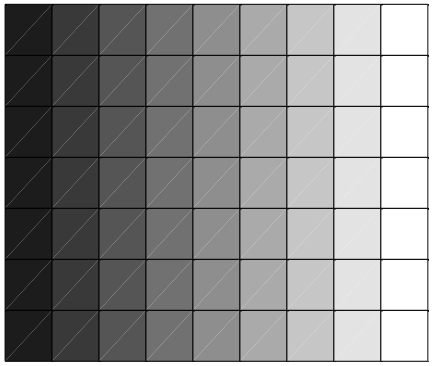
With this convention, and for the slave image presented above with size 7 × 9, the matrices X and Y are:

Matrix X that describes the rows



1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7

Matrix Y that describes the columns



1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9

The initialization consists in applying simple transformations (rotation, homothety) to image I_2 or general transformations, generally determined by the taking of tie-points.

The result is to have a slave image that has passed from the coordinate system (X_2,Y_2) to the coordinate system (X'_2,Y'_2) with the same dimensions as the master image. Therefore, this step is to have two images of same size and same geometry which corresponds to the requirements for the flow calculation.

There are two mainly different configurations:

- Either the images were acquired in the same geometry (two SAR images in interferometric conditions, VNIR and SWIR images). In this case, the transformation to be applied is reduced to a simple "crop" and / or translation. The slave image is not re-sampled.
- Or the images were acquired by sensors with different headings / resolutions. Then the transformation gives rise to a resampling of the slave image.

For the second case, the desired transformation is much more complex and it can be obtained by different methods whose choice depends of the configuration:

First case: simple transformation

In some cases, the transformation may correspond to known simple transformations: a homothety (only the sampling intervals of images are different) or a rotation (headings of the images differ).

A scaling can be done with the imresize matlab function, in case I1 and I2 are already in the same geometry:

```
Nx1=size(I1,1);
Nx2=size(I1,2);
I2prime = imresize(I2, [nx1,ny1]);
```

For a rotation, we apply the matlab function: imrotate

Second case : a complex transformation

For a more complex transformation, an initialization step is based on the selection of corresponding points between the two images and after on the estimation of a global transformation.

The selection of points into the images is done with the matlab function: cpselect

```
cpselect(I1, I2) ;
```

This operation leads to two lists of coordinates, those of the first image (master image) stored in the variable "input_points" and those of the corresponding points in the second image (slave image) stored in the variable "base_points".

From theses corresponding coordinates, the matlab command « cp2tform » is used to calculate the transformation that does the initial correspondence between pixels from on image to the other:

```
t = cp2tform(base_points,input_points,'affine');
```

Then, image I_2 is transformed into an image I_2' with the matlab command "imstransform" in according to the transformation previously estimated:

```
Nx1=size(I1,1);
Nx2=size(I1,2);
I2p = imtransform(I2, t,'nearest','XYScale',1,...
            'XData', [1,dimy],...
            'YData', [1,dimx],...
            'FillValues', eps);
```

Third case: initialization by geocoding

Finally, it is possible to assign to each image a grid of latitudes and longitudes for each pixel, obtained from all the georeferencing data (sensor trajectories and DTM) and then to resample the image I_2 in the referencial of image I_1.

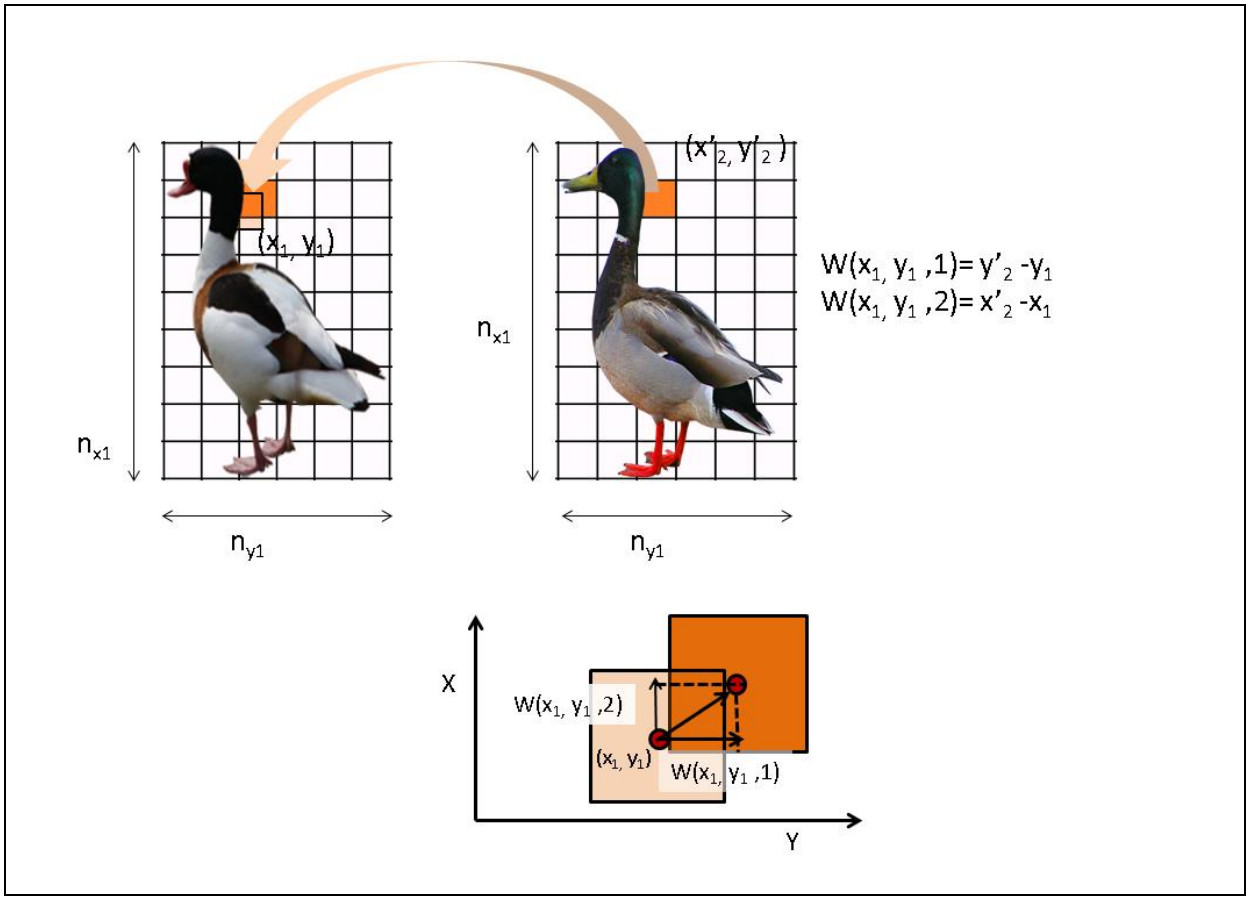
Because these operations are specific to each sensor, they are not described in this document.

DESCRIPTION OF THE MAIN STEP : FLOW CALULATION BY GEFOLKI

This step takes as input two images I_1 and I_2' of the same size.

The flow describes the transfer from coordinates (X_2',Y_2') to (X_1,Y_1) by a matrix **W** of size (n_{x1},n_{y1},2).

The first component of W is the y-displacement (column) and the second one is the x-displacement (row) to apply on the slave image



The GeFolki function is applied on two images I_1 and I_2' of the same size. The output is a matrix W corresponding to the flow matrix.

Below, you have a structure “para” that contains the parameters of the algorithm. This input is optional. If it is not specified, a default setting is provided.

```
para = struct('radius' , 32:-4:8, ...
    'levels' , 6, ...
    'iter' , 2, ...
    'contrast_adapt', false, ...
    'rank', 4);
```

1. The first parameter r = para.radius is the radius parameter. The algorithm can be launched for several radius sizes in an iterative manner. We usually start from the biggest radius to the smallest one. For this reason, it is defined as a decreasing vector.

   This radius r determines the size of the window (2r + 1) * (2r + 1) on which the correlation between the two images is maximized. Its choice results from a compromise between robustness and the level of detail for the flow:

   - A large radius makes the algorithm more robust
   - When the flow rapidly changes on the image, the radius must be chosen small enough to estimate these variations

2. The second parameter L = para.levels is the number of levels in the scale pyramid. It must be conditioned by the maximum size of the displacement to be estimated: Wmax < 2L.

3. The third parameter K = para.iter is the number of iterations used in the gradient method dedicated to the minimum search. Typically, this parameter varies between K= 2 and K=10.

4. The parameter para.contrast_adapt allows the algorithm to look for a contrast inversion. It must be active for heterogeneous images, and set to "false" for homogeneous images (SAR interferometry, etc.)

5. Parameter R = para.rank is the parameter used in the rank filter. A typical value of the parameter is R = 4. (9x9 window)

Once the structure has been defined, the algorithm can be launched with the command:

```
W=GeFolki(I1,I2p,para) ;
```

LAST STEP : RESAMPLING

Last operation is to transform the slave image to superpose it to the master image.

From the flow matrix W, this operation consists in resampling the images on the new grid of coordinates. Several methods of interpolation are possible: bilinear, linear, nearest neighbors, etc.

```
data1=W(:,:,1);
data2=W(:,:,2);
I3=(interp2(x',y',I2p',x'+data2',y'+data1','nearest'))';
```