Norsk Regnesentral
NORWEGIAN COMPUTING CENTER

www.nr.no
earthobs.nr.no

Adaptive Co-Registration of Remote Sensing Images

Line Eikvil, Marit Holden, Ragnar Bang Huseby

Norwegian Computing Center

ESA-EUSC IIM

ESRIN, March 4-6, 2008

Outline of presentation

- Problem and background
- Description of approach

  A first version was presented at ESA-EUSC IIM in 2005.
- Validation experiment

Problem

- Co-registration important in many remote sensing applications.
- Automatic techniques exist, but there is no one registration technique that works equally well for all image types.
- More than 90% of studies in remote sensing that could have used automated approaches for registration of images do not use them.
- The lack of a more general tool for helping in this process may be one of the reasons for this.
- Useful to have a more general tool for image registration that could be used for several applications.

Background

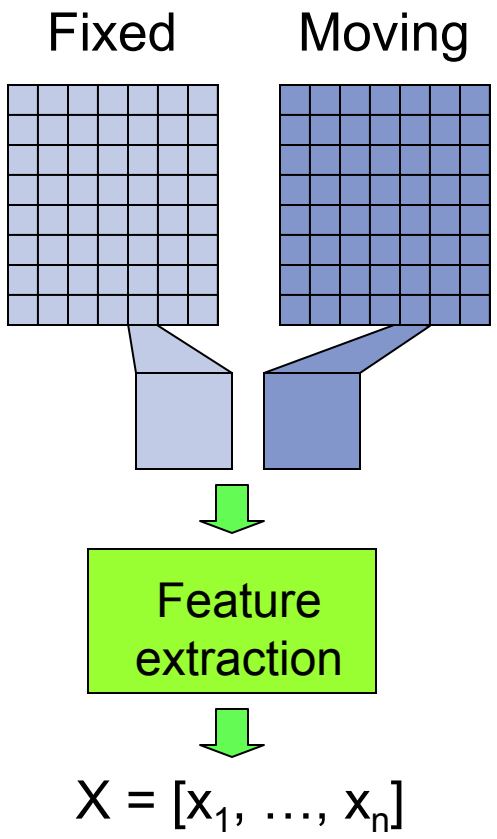
- A co-registration tool has been developed:
  - for homogeneous time series of images
  - which is general and can handle time series
    - From different sensors
    - With different contents
    - Acquired under different circumstances
- By using and adaptive approach providing:
  - a selection of different methods
  - and intelligence enabling selection of the most appropriate method for each problem.
- Objective of this work:
  - Improve the co-registration tool
  - Validation

Overview of approach

- Feature extraction
  - Images are divided into regions.
  - Features are extracted from each region
- Selection of regions and methods
  - The expected performance of each method is predicted.
  - Regions and methods are selected based on the predictions.
- Transform estimation
  - Local co-registration is performed with the selected method.
  - A global transform is estimated from the set of local transforms.

Feature extraction

- The images are subdivided into rectangular regions.
  - Regions can be discarded.
  - Different methods can be used for different regions.
- Features are extracted from a pair of regions.
- The features from the two regions are merged into a joint feature vector.

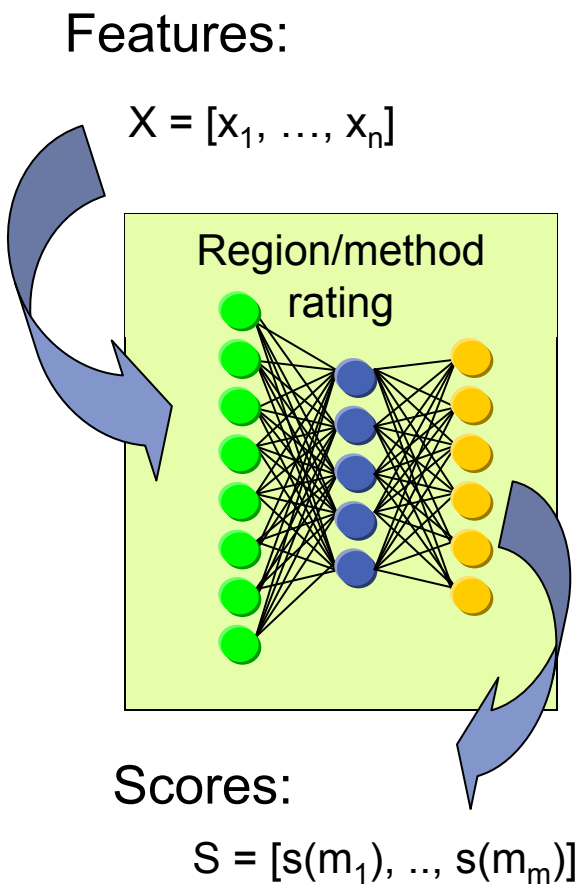


Features

- GLCM (Gray Level Co-occurrence Matrix)
- Difference between features in the fixed and the moving image
- Registrability features (sensitivity to transformations).
- Gradient measures.
- Statistics based on zone means.

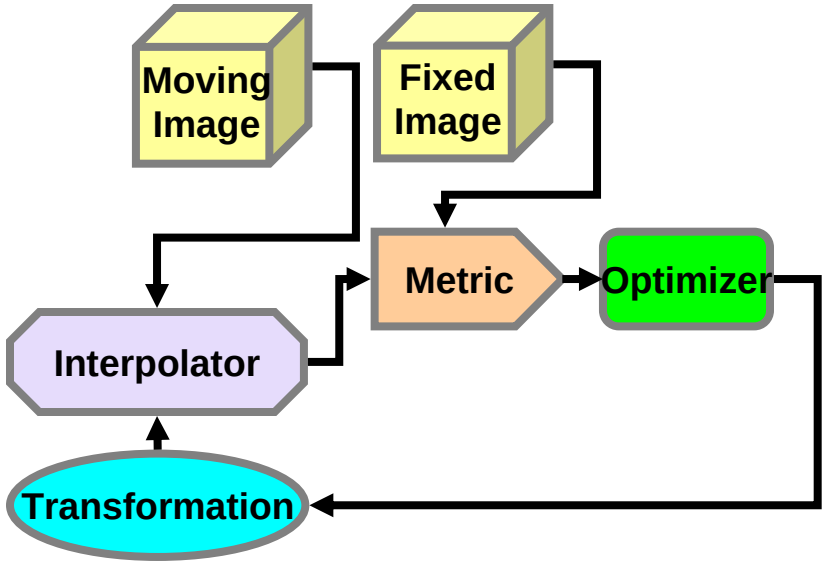
Region and method selection

- From the extracted features a neural net is used to predict the performance of each method for each region.
- Regions with low scores are discarded.
- For each of the remaining regions the method with the best score is selected.
- Local region matching can then be performed with the selected method.



Methods for region matching

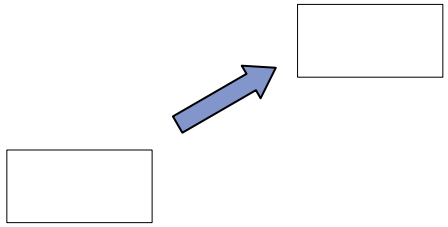
- Metric
  - Normalized cross-correlation
  - Mean squares
  - Mutual information (three different varieties)
- Optimizer
  - Gradient Descent
  - Regular step gradient descent
  - Genetic algorithm
- Matching method: a combination of a metric and and optimizer.
- 15 methods/combinations



Types of local transformations

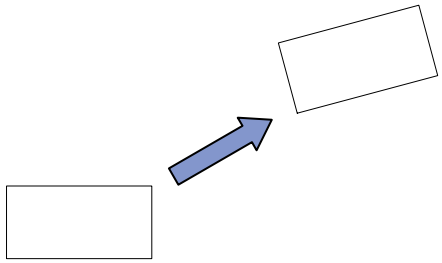
- Translation

  (t_1, t_2)



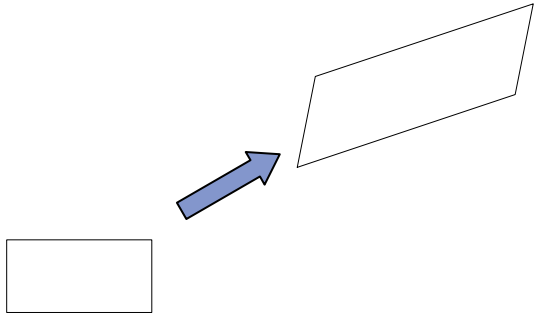
- Translation and Rotation

  (t_1, t_2, t_3)



- Affine

  $(t_1, t_2, t_3, t_4, t_5, t_6)$



Outlier removal

- The selected matching method is used to estimate a transformation for each of the selected regions.
- The set of estimated transformations is analysed to remove outliers.
- Outlier removal is based on a model for the transformation parameter:

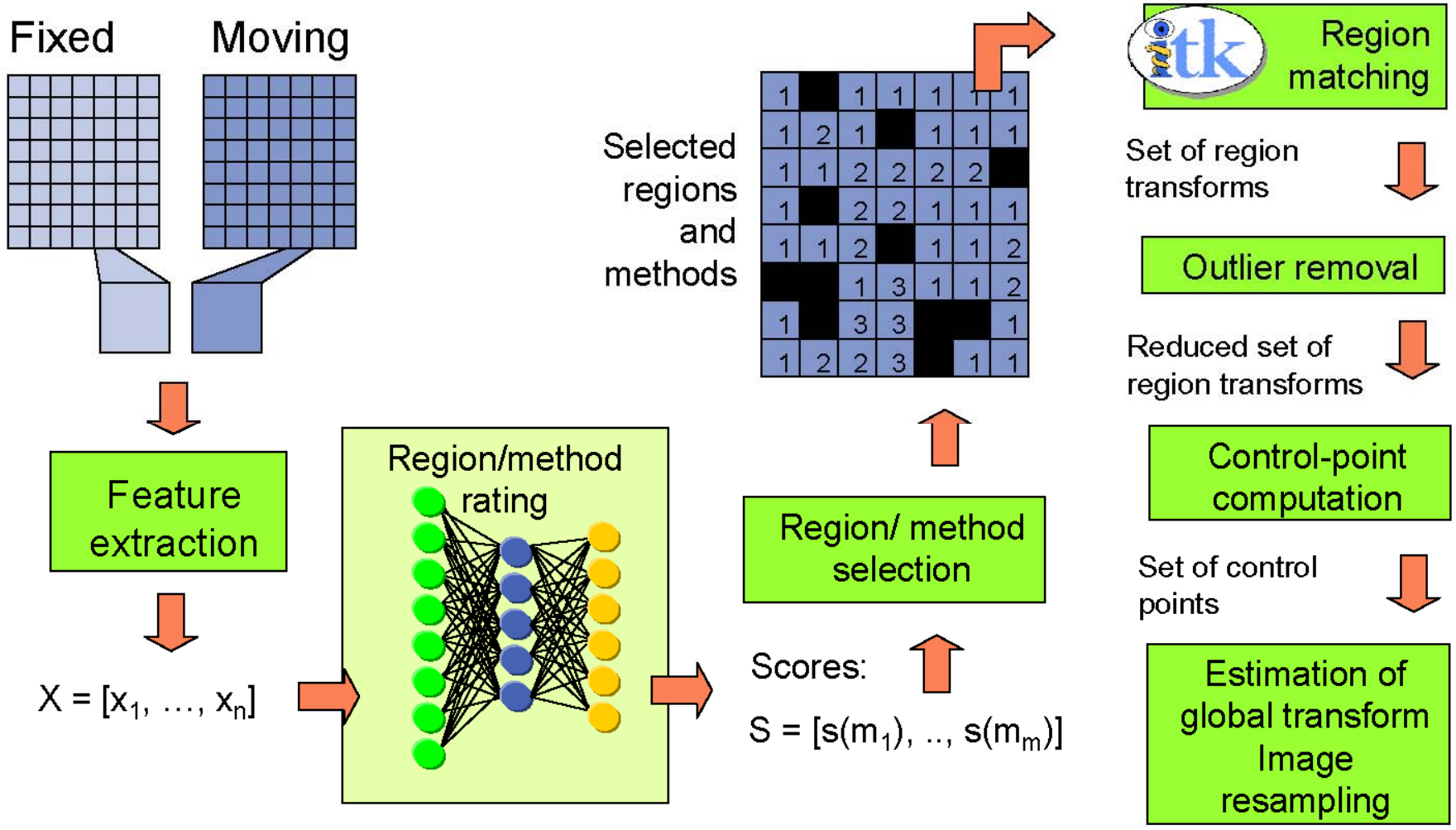
  $t_i = a + bx + cy,$ (x,y) = centre of region

- a, b and c are estimated using a robust regression.
- Transformations corresponding to large residuals are removed.

Transform estimation

- Control points are computed for each of the remaining regions based on estimated transformations.
- A global transform is computed from the set of control points
- The image is resampled according to the global transform.

Overview of the process

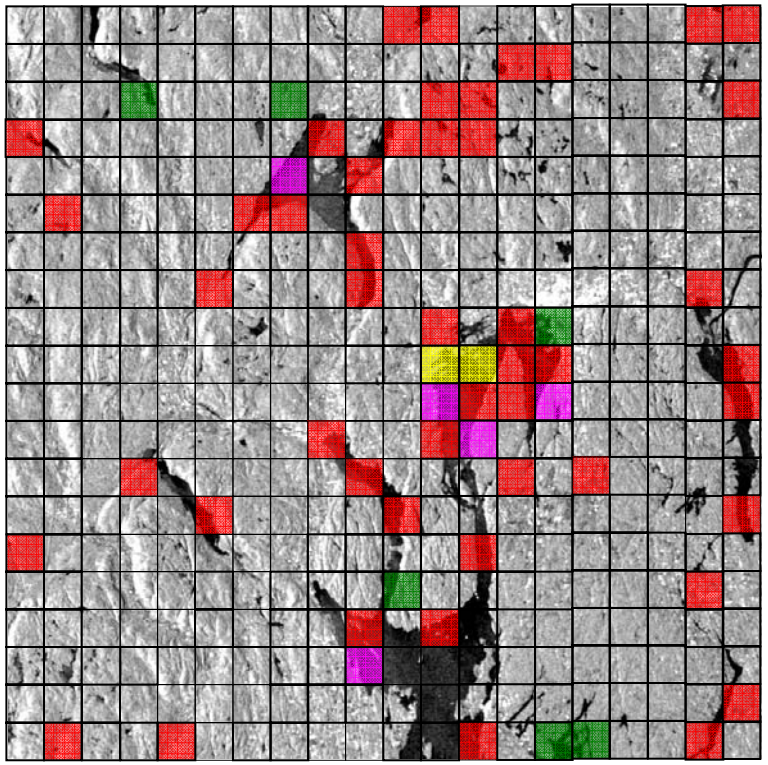


Validation experiment

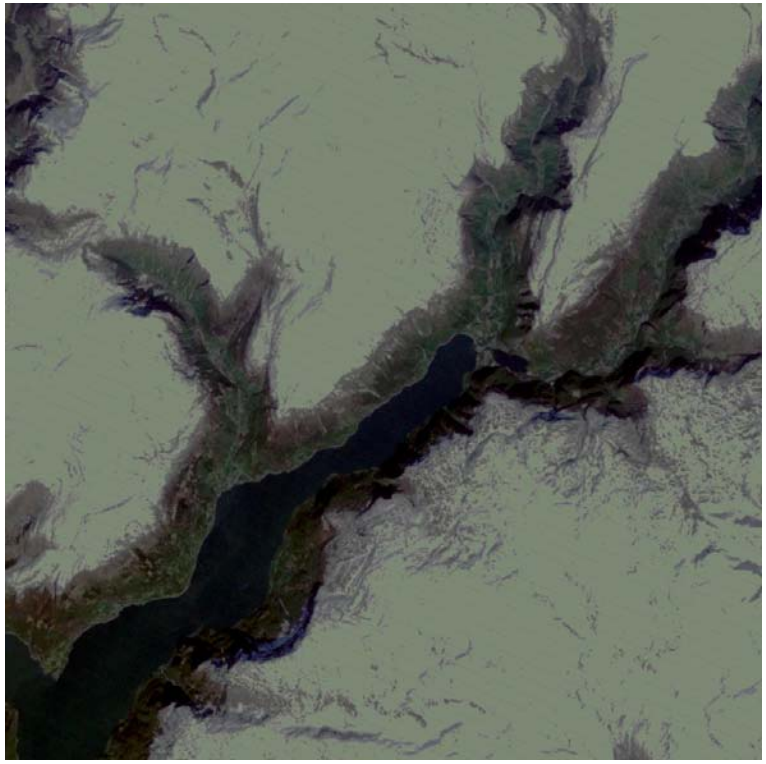
- Test set contains image pairs (1000 × 1000 pixels) consisting of:
  - two Envisat ASAR images,
  - two Landsat TM images,
  - two NOAA-AVHRR images,
  - one Quickbird image and a transformation.
- Training set: similar (and MODIS) images covering different areas
- The relative distortion is known:
  - translation (by 0, 2, 4, 8 pixels),
  - enlargement (by 0.5, 1, 2 percent)
  - rotation (by 0.25, 0.5, 1 degrees) or
  - combination (T2+E0.5+R0.25, T4+E1+R0.5).
- Result: RMS errors within a pixel
- The system does not handle larger distortions.

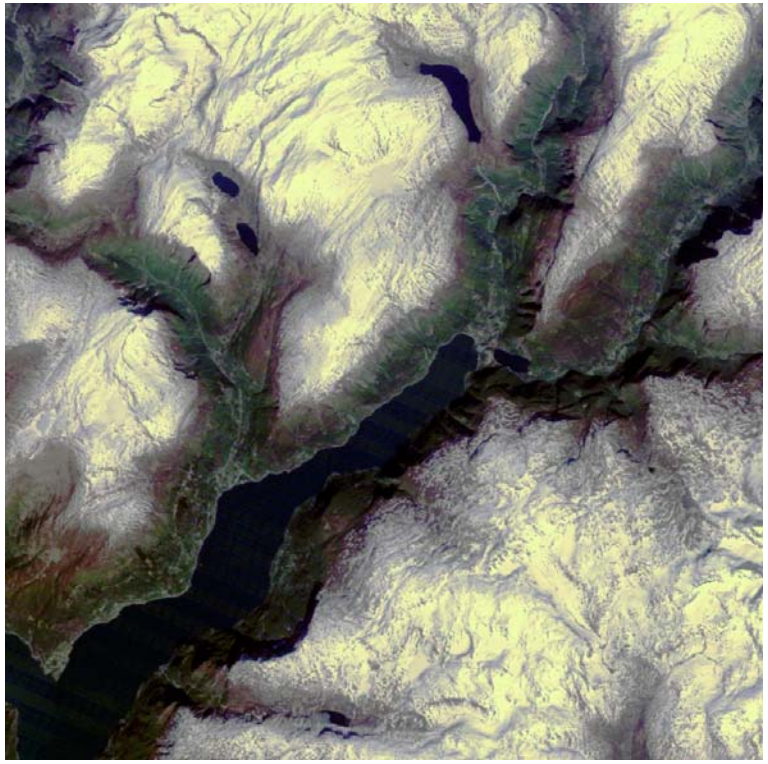
Envisat ASAR

Envisat ASAR
Selection of methods and regions

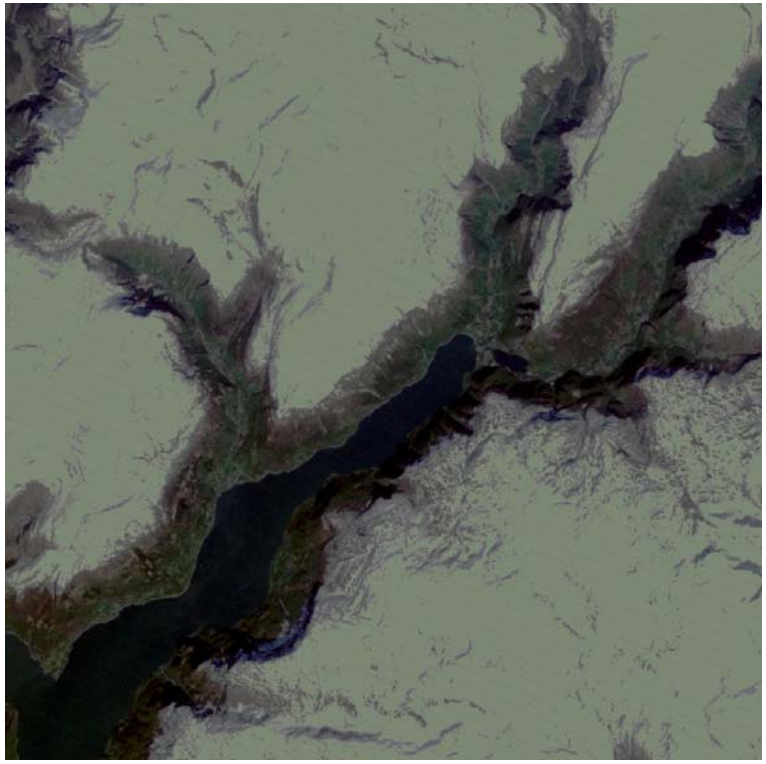


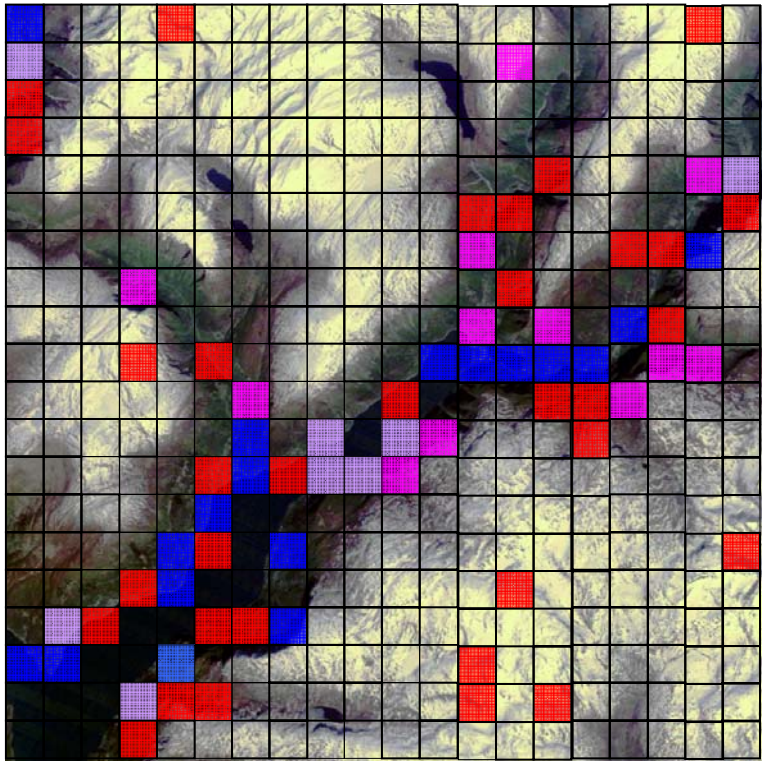
Landsat TM



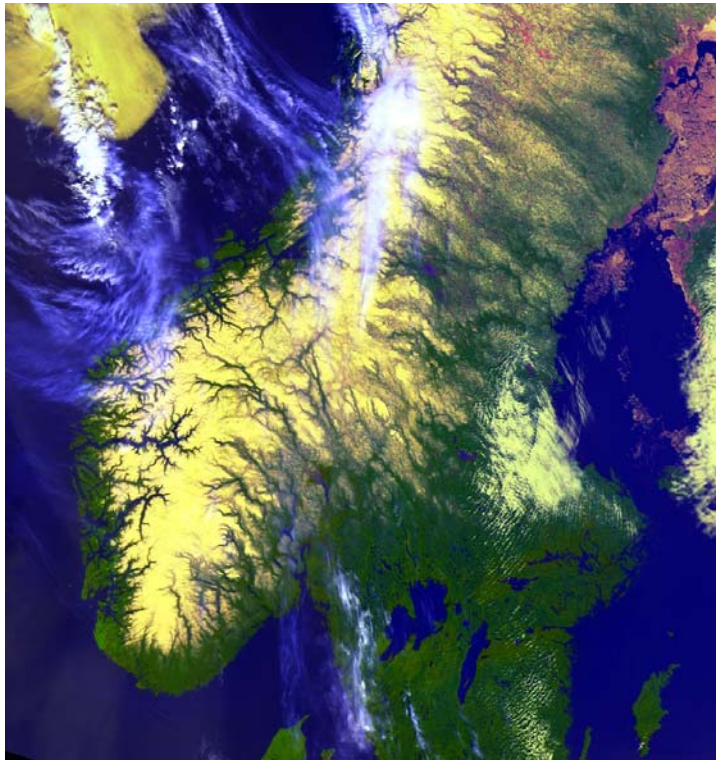


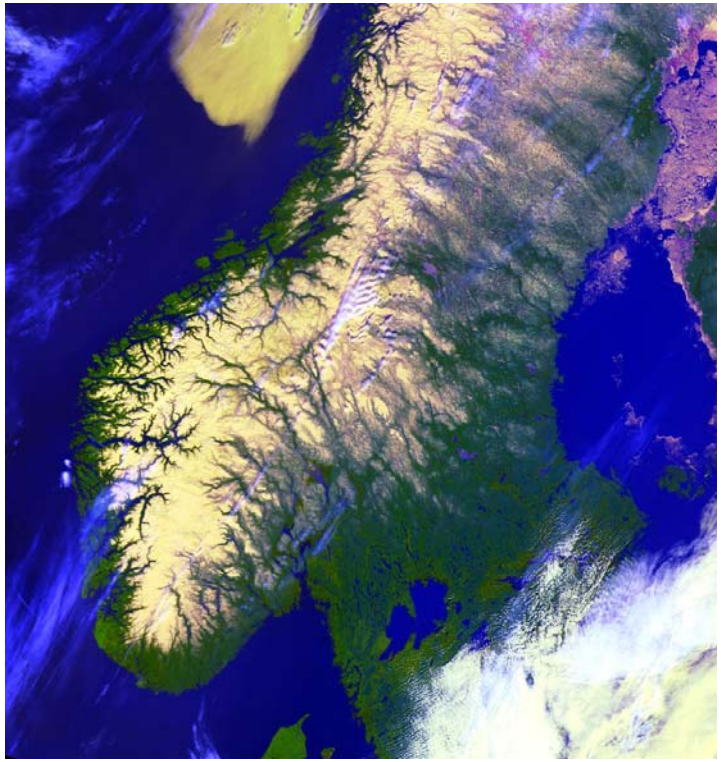
Landsat TM
Selection of methods and regions



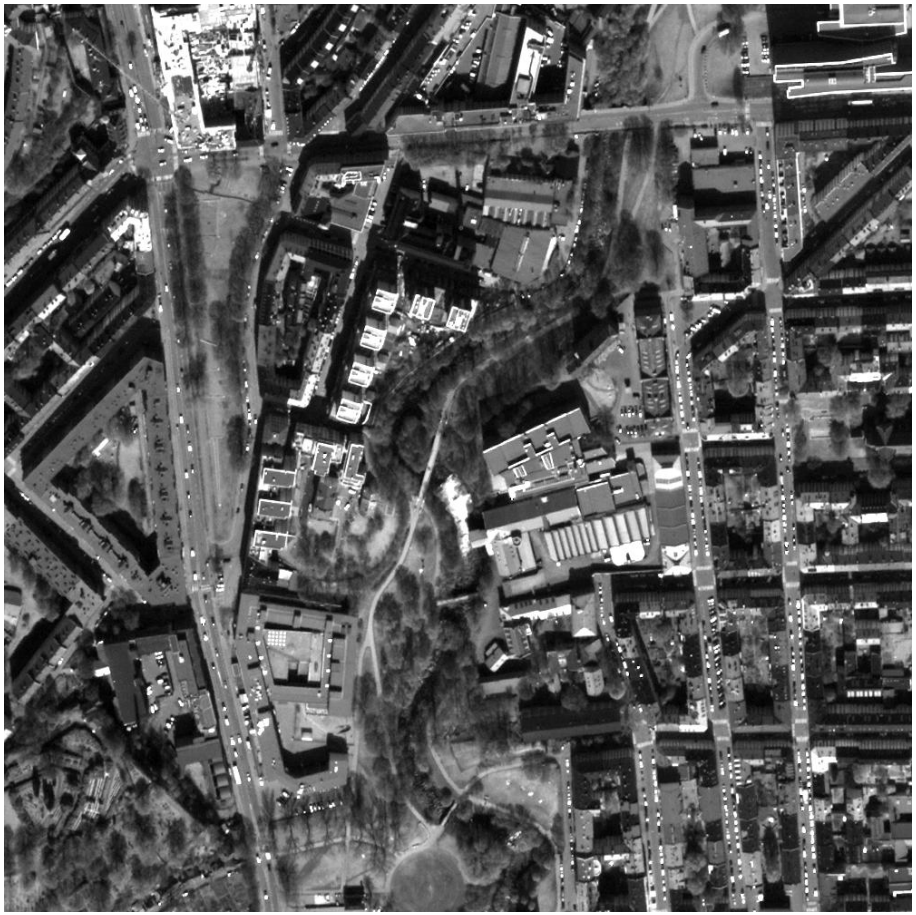


NOAA-AVHRR

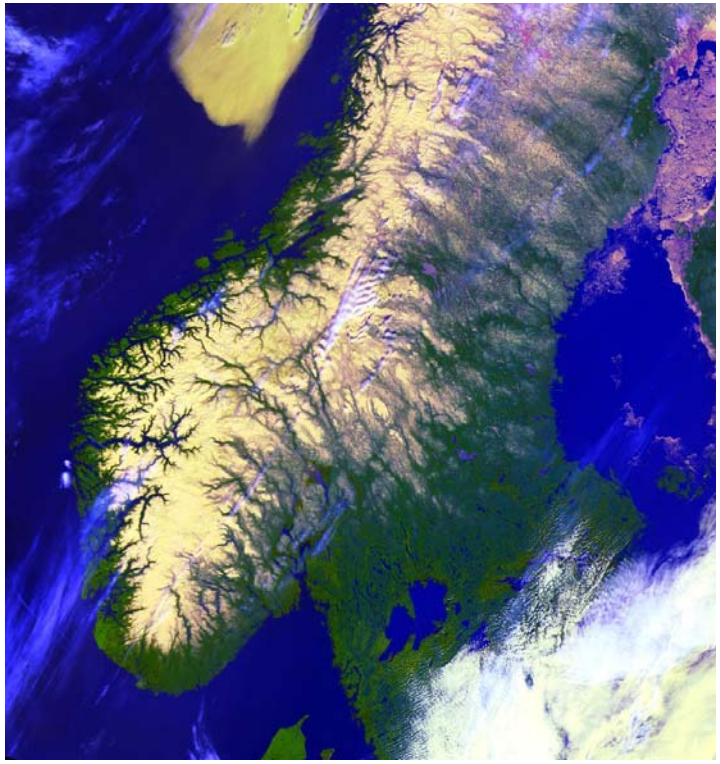


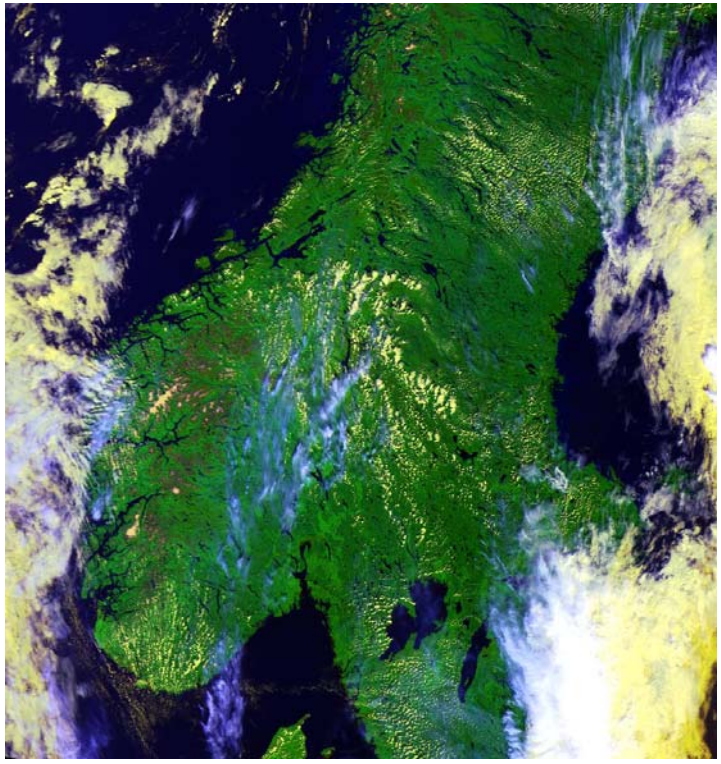


Quickbird



The system does not handle





Summary

- A software tool for adaptive co-registration of remote sensing image has been improved.
- The software tool has been tested on time series of optical and radar earth observation images.
- The results are promising when
  - The content of the two images is not too different
  - The distortion is not too large
- Improvements
  - Multi-resolution strategy
  - Cloud detection

Acknowledgement

- This work has been supported by ESA.