Adaptive Co-Registration of Remote Sensing Images

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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.

\[ X = [x_1, \ldots, x_n] \]
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.

\[
X = [x_1, ..., x_n]
\]

\[
S = [s(m_1), .., s(m_m)]
\]
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 an 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:
  \[ t_i = a + bx + cy, \quad (x,y) = \text{centre of region} \]
- \( a, b \) and \( c \) are estimated using a robust regression.
- Transformations corresponding to large residuals are removed.
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

Fixed

Moving

Feature extraction

Region extraction

Region/Method
rating

Region/Method
selection

Scores:

\[ S = [s(m_1), \ldots, s(m_m)] \]

Selected regions and methods

Set of region transforms

Outlier removal

Reduced set of region transforms

Control-point computation

Set of control points

Estimation of global transform

Image resampling

Region matching
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
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

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