Automatic Registration for On Ground and On Board Processing

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Image Registration

Definition

"Exact pixel-to-pixel matching of two different images or matching of one image to a map"

Navigation or Model-Based Systematic Correction

Orbital, Attitude, Platform/Sensor Geometric Relationship, Sensor Characteristics, Earth Model, etc.

Image Registration/Feature-Based Precision Correction

Navigation within a Few Pixels Accuracy

Image Registration Using Selected Features (or Control Points) to Refine Geo-Location Accuracy

Image Registration as a Post-Processing or as a Feedback to Navigation Model

Role of Image Registration in Remotely Sensed Data

- Essential for spatial and radiometric calibration of multitemporal measurements for creating long-term phenomenon tracking data
- Used for accurate change detection
- Basis for extrapolating data throughout several scales for multi-scale phenomena (distinguish between natural and human-induced)

Challenges in Image Registration

Navigation Error (or varying “Initial Conditions”)

- Historical satellites (e.g., Landsat-5 compared to Landsat-7)
- Following a maneuver (e.g., star tracking)

Needs:

- Sub-pixel accuracy
- Robustness to recurring use
- Speed and High-Level of Autonomy (Near- or Near-real time applications, e.g., disaster management)
- On the ground or On Board Processing

Image Registration Components

0 Pre-Processing

- Cloud Detection, Region of Interest Masking, …

1 Feature Extraction (“Control Points”)

- Gray Levels, Salient Points (e.g., Edges, Edge-like such as Wavelet Coefficients, Corners), Lines, Contours, Regions, Scale Invariant Feature Transform (SIFT), etc.

2 Feature Matching

- Choice of Spatial Transformation (**function f**: a-priori knowledge)
- Choice of Search Strategy :
  - Global vs Local, Multi-Resolution, Optimization, ...
- Choice of Similarity Metrics
  - L2-Norm, Normalized Cross-Correlation, Mutual Information, Hausdorff Distance, …

3 Remapping/Resampling (**function g**: if necessary)

Global Land Survey Maps

- A collection of Landsat-type satellite images from USGS
  - Near complete global coverage
  - Orthorectified
  - Each image has cloud cover of less than 10%
  - Four versions: 1970, 1990, 2000, and 2005
- Ground truth for the registration programs was drawn from the GLS 2000 and can be updated when the GLS 2010 is completed
- http://landsat.usgs.gov/science_GLS.php

Image Registration

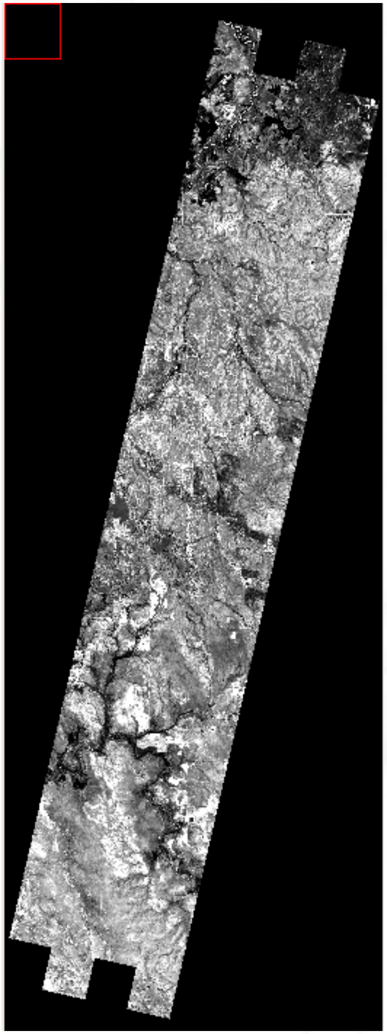
- First Method: Co-register 2 full size images
  - Compares image with a previously geo-corrected ground truth image
  - Uses GLS 2000 dataset stored on the cloud

Step 1) Script automatically selects a GLS map for the EO1 scene using scene metadata

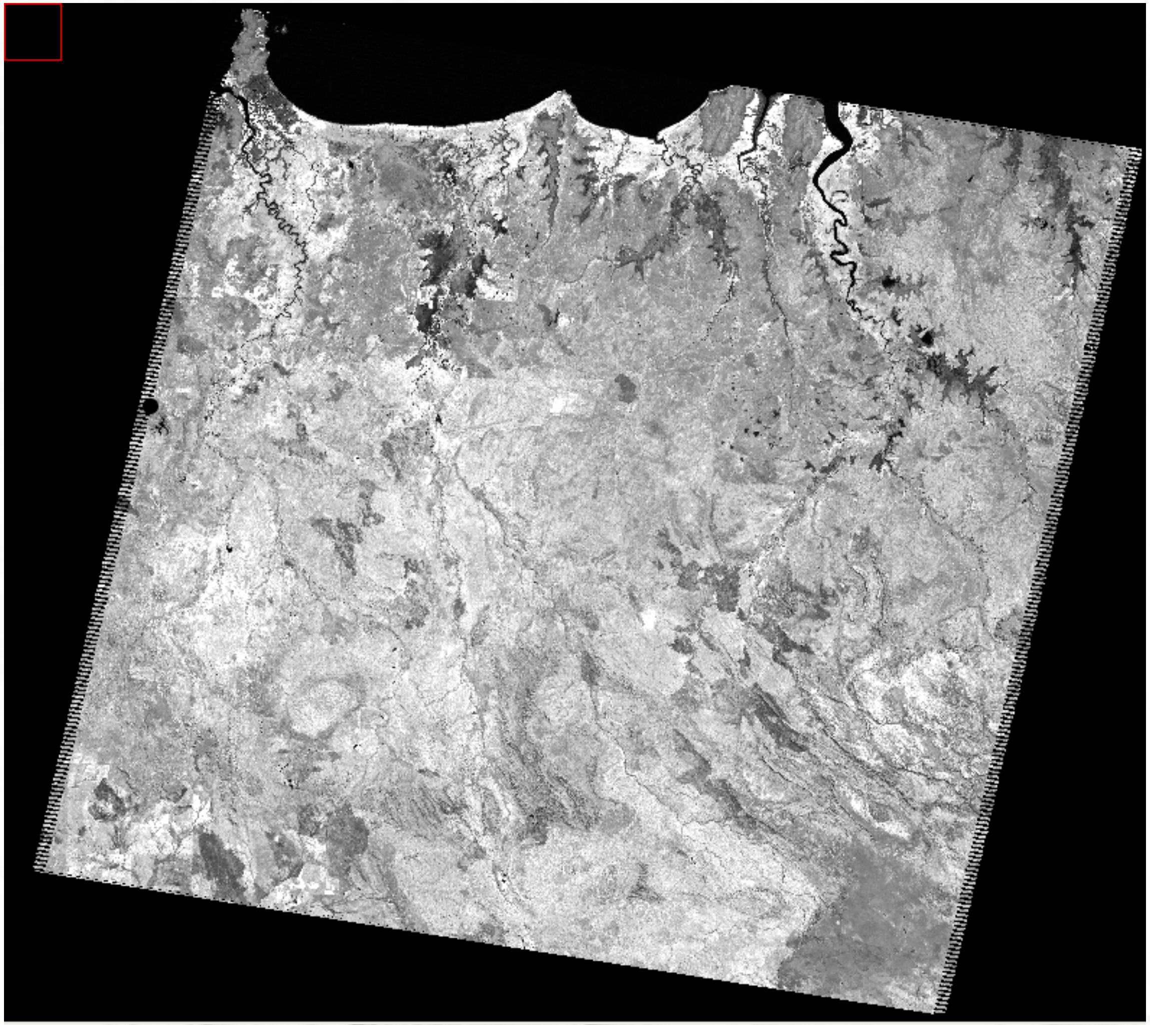
Step 2) Registration program automatically selects ground control points and finds the transformation between the two images

GLS Co-registration

- Step 1: EO1 scene and selected GLS map



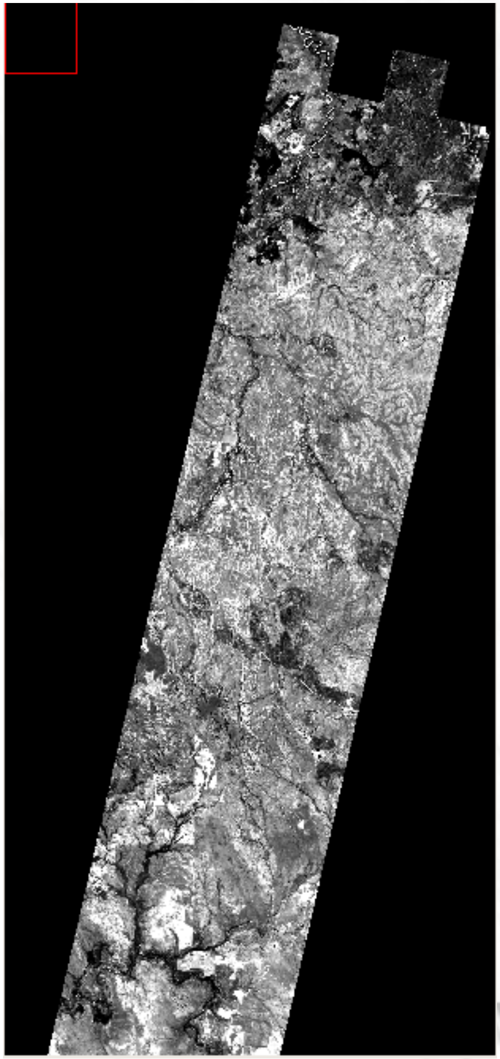
EO1 Scene



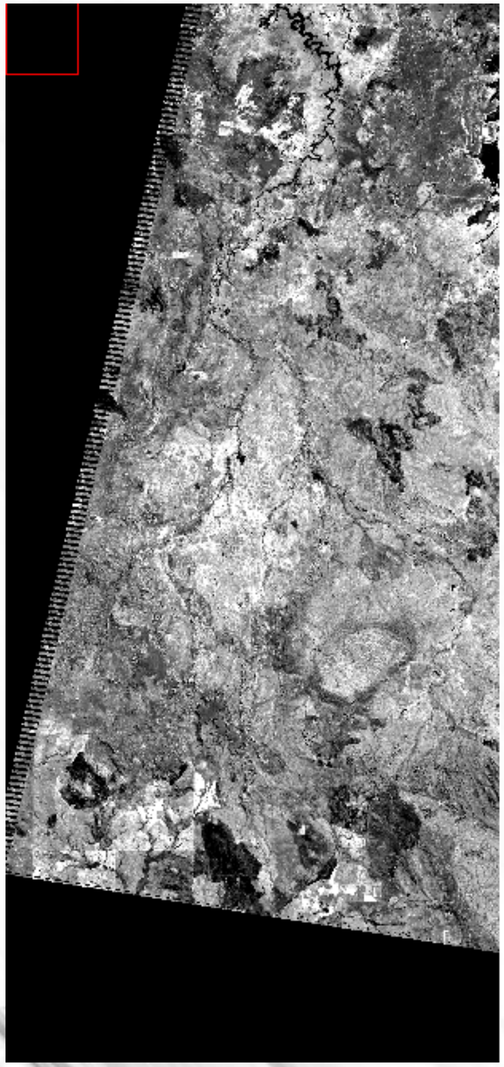
Corresponding GLS map of area

GLS Co-registration

- Step 2: Crop scenes to overlapping region



Cropped EO1 Scene



Cropped GLS map

GLS Co-registration

Step 3: Extract features over multiple passes

Step 4: Compute best transformation between these features

- Returns transform to align image:

TransX = 11.0 px

TransY = -.851 px

Rotation = -0.0007 deg

- Manual Results:

TransX = 11 px

TransY = -1 px

Rotation = 0 deg

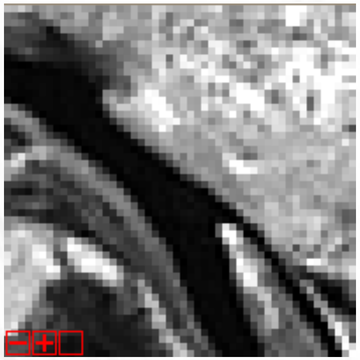
Registration with Chips

- Second Method: Co-register many regions of an image with “chips”
  - A lighter, faster method of registration
  - Using our database of chips from all over the world generated from the GLS 2000 maps

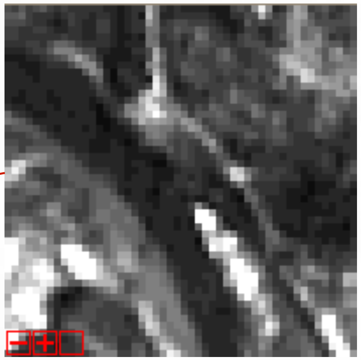
Step 1) Using basic information about where the EO1 scene was taken, the program finds chips that overlap the scene

Step 2) Co-registers these smaller areas and combines their local transformations to get the global transformation

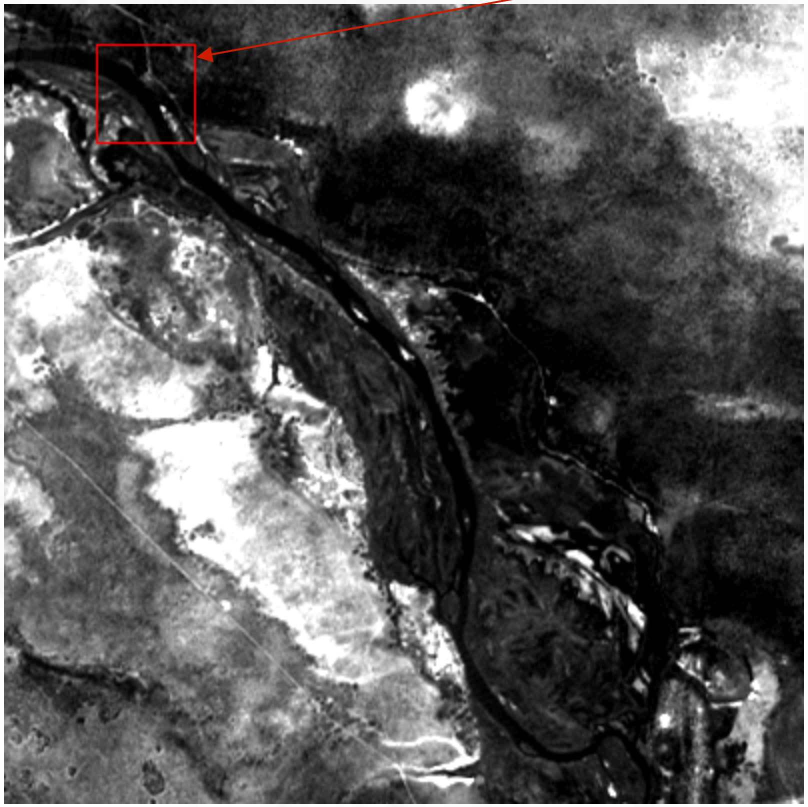
Chip Registration



Overlapping chip from database



Chip extracted from EO1 scene



Area in EO1 scene where chip was extracted

Initial Results

- Initial testing has been performed on approximately 10 scenes for each method
- Full Scene Registration results:
  - Worst case overall error was 2-pixel, several tests gave results with subpixel accuracy
  - Uses a large amount of memory and time so best for use on ground with previously captured images
- Chip Registration results:
  - On current test chips performs much faster and with much less memory
  - Takes a matter of seconds
  - Initial results are on par with the first method

Future Directions: On Board Registration

- The chip-based method is much faster and less resource-demanding, so is ideal for on board image registration
- In the future, the method can be parallelized by doing the independent chip co-registration on separate threads
  - This can be done using AESOP and can then be used on SpaceCube or the future MAESTRO
- So close to or real time image registration can be achieved on board, eliminating a large amount of post-processing