Image Registration with High-Resolution SAR Data

A New Operational Approach

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INTRODUCTION

BACKGROUND For many image processing workflows an accurate and automated image-to-image registration is a critical precondition. Particularly registering images with different modalities (e. g. Optical to SAR) is a known challenging problem.

OBJECTIVES Improvement of the accuracy, performance, and automation of tie point generation and image registration, with a focus on multisource data.

Generation of an automated geospatial workflow for operational applications.

RESOURCES TerraSAR-X SpotLight image, GEC product, GSD 1,25 m (base image) and Pléiades 1a multispectral image, processing level primary, with RPCs, GSD 0.5 m, pan-sharpened (warp image). ENVI, IDL, and ArcGIS®.

"HyPARE" REGISTRATION ENGINE

KEY COMPONENTS The Hybrid Powered Auto-Registration Engine (HyPARE) automatically and accurately generates tie points, and then uses them to align and resample the warp image to the base image.

It combines available spatial reference information with various auto-registration techniques to improve the accuracy, performance, and automation of auto-registration, and minimizes or eliminates the need for user interaction and editing.

For multisource data we implemented an optimized mutual information-based matching method, which produces more accurate results than traditional correlation-based measures.

The HyPARE algorithms form the core of the image registration functionality within the ENVI platform.

IMAGE REGISTRATION WITH "HyPARE"

SPATIAL REFERENCE The spatial reference information may be generated from the following sources:

- Standard map information or RPC information of the input images establishes the approximate geometric relationship between a warp image and a base image. It reduces the search space and improves the reliability of automatic tie point generation.
- Geolocation geometric constraints are used to search for and to filter tie points.
- For images taken at different viewing positions and/or angles two epipolar geometry models are used in geometric filtering.
- RPC sensor models and elevation are used for orthorectification on-the-fly during image registration.

AUTOMATION

The HyPARE algorithms are embedded in an IDL-based task system. This makes it possible to integrate the image registration e. g. into the ArcGIS® platform or to make it available as a web service via the ENVI Services Engine.

The registration of optical imagery to high-resolution SAR images is represented by the following tasks:

GenerateTiePointsByMutualInformation performs automatic tie point generation using mutual information as a similarity measure.

FilterTiePointsByGlobalTransform uses the global transform to filter tie points. For satellite imagery, the transformation model between the optical and the SAR image fits a first-order polynomial transform.

ImageToImageRegistration warps the optical image to align with the base SAR image using the previously generated and filtered tie points.

IMPLEMENTATION IN OPERATIONAL ENVIRONMENTS

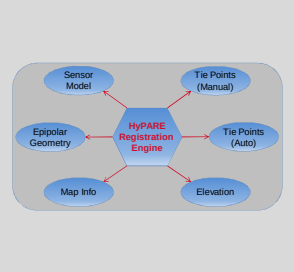
The HyPARE-based image-to-image registration can be embedded in virtually any existing geospatial workflow for operational applications.

Tested integration options are:

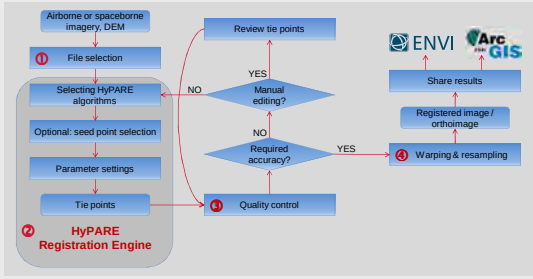
- Deployment within service-based information systems, notably ArcGIS®. This allows to make the application available to organizations through their Portal for ArcGIS® website.
- Publishing the image registration tasks as web-based services via the ENVI Services Engine (ESE) to existing enterprise infrastructures or cloud solutions.
- General implementation in geospatial workflows using the IDL bi-directional Python bridge.

CONCLUSION

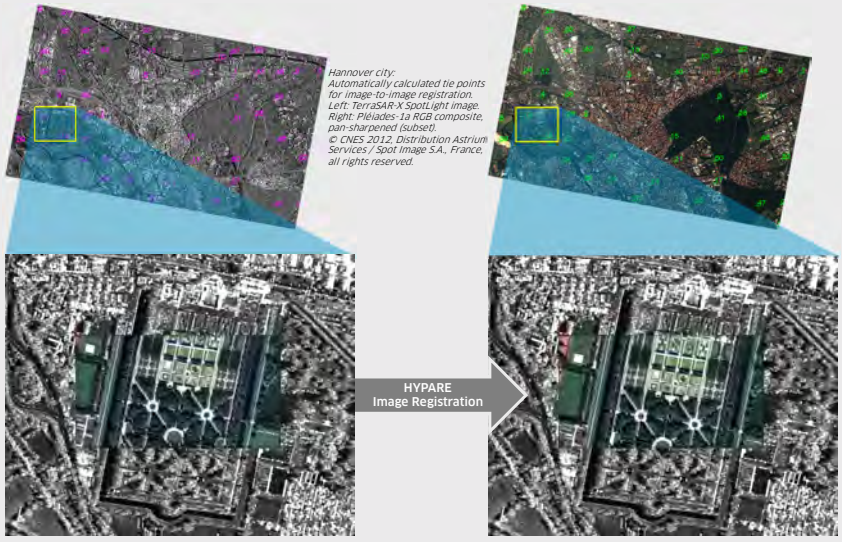
- With the Hybrid Powered Auto-Registration Engine (HyPARE) we developed an approach to generate tie points accurately and to geometrically align images of multiple sources automatically.
- HyPARE is robust in situations of images obtained from different viewing angles, in different time and seasons, and by sensors with different modalities.
- We demonstrated this successfully by the registration of a Pléiades-1a image to a TerraSAR-X SpotLight image of Hannover, Germany.
- The simple implementation in online services with the technology of HARRIS and ESRI makes it possible to calculate and retrieve tailored, individual analyses for user-defined areas on-the-fly.



Key components of the Hybrid Powered Auto-Registration Engine (HyPARE).



Implementation of the HyPARE algorithms in an interactive ENVI workflow for image-to-image registration.



Hannover city: Automatically calculated tie points for image-to-image registration. Left: TerraSAR-X SpotLight image. Right: Pléiades-1a RGB composite, pan-sharpened (subset). © CNES 2012, Distribution Astrium Services / Spot Image S.A., France, all rights reserved.

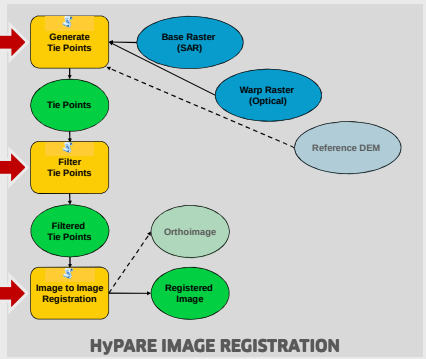
Unregistered Pléiades-1a image on TerraSAR-X SpotLight image, Hannover, Great Garden. © CNES 2012, Distribution Astrium Services / Spot Image S.A., France, all rights reserved.

Registered Pléiades-1a image on TerraSAR-X SpotLight image, Hannover, Great Garden. © CNES 2012, Distribution Astrium Services / Spot Image S.A., France, all rights reserved.

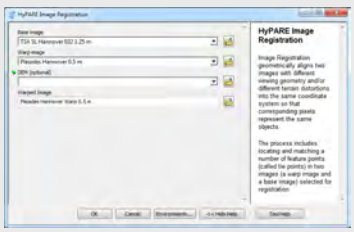
```
; Get the auto tie point generation task
TiePointTask = ENVITask('GenerateTiePointsByMutualInformation')
TiePointTask.INPUT_RASTER1 = rasterBase
TiePointTask.INPUT_RASTER2 = rasterWarp
TiePointTask.INPUT_SEED_TIEPOINTS = tiePoints
TiePointTask.MATCHING_WINDOW = 26
TiePointTask.MINIMUM_MATCHING_SCORE = 0.010
TiePointTask.REQUESTED_NUMBER_OF_TIEPOINTS = 288
TiePointTask.SEARCH_WINDOW = 26
TiePointTask.Execute

; Get the tie point filter task
FilterTask = ENVITask('FilterTiePointsByGlobalTransform')
FilterTask.INPUT_TIEPOINTS = TiePointTask.OUTPUT_TIEPOINTS
FilterTask.Execute

; Get the image-to-image registration task
RegistrationTask = ENVITask('ImageToImageRegistration')
RegistrationTask.INPUT_TIEPOINTS = FilterTask.OUTPUT_TIEPOINTS
RegistrationTask.OUTPUT_PIXEL_SIZE = [0.6, 0.6]
RegistrationTask.OUTPUT_RASTER_URI = e.GetTemporaryFilename('.dat')
RegistrationTask.RESAMPLING = 'Cubic Convolution'
RegistrationTask.WARPING = 'Polynomial'
RegistrationTask.Execute
```



IDL script (above) with ENVITasks used to run the registration of optical imagery to high-resolution SAR images in the ArcGIS® ModelBuilder (right) .



HyPARE-based image registration in ArcGIS® using a customized script tool.

```
import envipy, arcpy

inputBase   = arcpy.GetParameterAsText(0)
inputWarp   = arcpy.GetParameterAsText(1)
inputDEM    = arcpy.GetParameterAsText(2)
outputOrtho = arcpy.GetParameterAsText(3)

toolname = 'registerOpticalOnSARinArcGIS'

envipy.RunTool(toolname,
               inputBase, inputWarp,
               inputDEM, outputOrtho)
```

The Python script file retrieves the parameters from the user interface and runs the precompiled IDL code. The IDL code interfaces between the Python script and the relevant ENVITasks.