RUGGED@ESA

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What is Rugged?
https://www.orekit.org/rugged/

« A sensor-to-terrain mapping tool »
1) Define sensor pixels

A line of sight for each pixel
1) Define sensor pixels
2) Define transforms to spacecraft

Transforms from sensor to spacecraft
- Rotations
- Translations
- Homothety
1) Define sensor pixels
2) Define transforms to spacecraft
3) Define datation model

Sensing start time and stop time, frequency
→ Map acquisition lines with dates
→ Earth reference frame
1) Define sensor pixels
2) Define transforms to spacecraft
3) Define datation model
4) **Define spacecraft orbit**

Spacecraft position, velocity, attitude quaternion during sensing period
1) Define sensor pixels
2) Define transforms to spacecraft
3) Define datation model
4) Define spacecraft orbit
5) Geolocate on DEM

- Geolocation: Sensor coordinates to geodetic point
- Inverse geolocation: Geodetic point to sensor coordinates
All this can be done in a few tens of lines, as presented in tutorials

https://www.orekit.org/forge/projects/rugged/wiki/Tutorial
Birth
 Sentinel-2 Instrument Data Processor developed at CS

- Radiometric corrections: dark current correction, equalization, defective pixel correction, etc.
- Geometric corrections and metadata: orthorectification of images, product footprints, etc.

The project needed a replacement library to

- Implement instrument viewing model
  - Using sensing time, position and velocity, attitude, viewing directions, corrections
- Geolocate pixels
  - Projection to digital elevation model (DEM)
  - Inverse location from ground to detector coordinates
- Ingest and process all data related to geometry correction
Combine

› CS **Space dynamics** team: Orekit library management of time scales, Earth referential, orbits, interpolators

› CS **Earth observation** team: management of DEM, sensor geometry (linear detectors with line of sight for each pixel)

… to build the new library.

Images: ESA
Inside Rugged
Design Drivers

- Built on top of Orekit and Hipparchus
- Built for the immediate need (Sentinel-2) but extensible
- Lightweight
- Fast, state of the art location algorithm : Duvenhage
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Overview

- Image processing application
- Mission specific interface
- Mission independent Rugged library
  - Orekit (≥ 8.0)
  - Hipparchus (≥ 1.0)
- Java Standard Edition (≥ 8)
What it does

- Define push-broom sensors
- Define (time-dependent) geometric transforms
- Load and interpolate position/velocity and attitude from data points
- Manage large DEMs as tiles
- Earth frames from Orekit. Not limited to location on Earth…
What it does not do (yet ?)

- Sensor concepts other than push-broom
- Manage data formats. Rugged is currently agnostic to data formats
  - This is handled by a mission-specific interface (i.e S2Geo library for S2)
- Refinement of sensor geometry based on ground control points
  - To be released in next version
How it performs

Location accuracy

- Earth model from Orekit is accurate
  - $\delta \Delta \psi$, $\delta \Delta \epsilon$ on precession nutation
  - $\Delta UT_1$, iod on proper rotation
  - $u$, $v$ pole wander (polhody)

- Ray corrections
  - Light time correction, aberration of light correction, line-of-sight curvature in geodetic coordinates, atmospheric refraction

- Location accuracy is only limited by measurement errors. Rugged can handle very high resolution sensors
How it performs

- Time performance
  - Direct location: 98500 points per second
  - Inverse location: 53000 points per second

Intel Xeon 56xx with 8GB of RAM, single core
Applications
Sentinel-2 Instrument Data Processor

- Sentinel-2 Mission
  - Part of the Copernicus Earth Observation Programme (30 satellites)
  - Two satellites S2A & S2B for a revisit period of 5 days
  - Optical imagery for land services

Image: ESA
Sentinel-2 Instrument Data Processor

- Sentinel-2 instrument
  - 12 detectors with 13 spectral bands (10m, 20m or 60m) for VNIR & SWIR sensing
  - 2592 pixels per 10m band, 640 lines per second
  - About 109 million pixels per second to process
Sentinel-2 Instrument Data Processor

- Rugged is used in the processing chain to
  - Orthorectify images
  - Compute product footprints
  - Geolocate quality masks
What is the SEOM Element?

- Scientific Exploitation of Operational Missions
- Objective = Enabling research community to extensively exploit data from European operational Earth Observation missions

Study 2: Atmospheric corrections for coastal and inland waters Algorithms.

- One studied algorithm is the masking of topographic shadows based on DEM.
SEOM

- Rugged in SEOM topographic shadow masking
  - Sun location is easily retrieved at date of sensing using Orekit
  - Define vector SA from sun S to ground point A as a line-of-sight as if the sun was the sensor!
  - Geolocate on DEM to get B and detect any large AB
SEOM

Result of successful shadow masking in Etretat cliffs.
Future
Future

➤ New developments

  › Sensor geometry refinement using ground control points
  › Support for matrix sensors

➤ Rugged Project Management Committee