Monitoring Mining Areas from Space

InSAR technology as a tool for the evolution of mining industry

Fernando Bellotti
Geospatial World Forum, Rotterdam, 4th May 2023
Introduction

• Implementing a risk management and mitigation program is a necessary way to ensure safe and profitable a mining operation.

• Since it’s beginning in 1992, InSAR has grown to be an easy-to-integrate companion of in-situ monitoring instrumentation and has proven itself as an effective technology for monitoring surface deformation.

• InSAR is now recognized as a reputable monitoring solutions thanks to its capability of extending the monitoring scale to the entire mine site facilitating strategic monitoring.
Hazard Mitigation and Risk Reduction

• Increasingly important for mining operations as highlighted by recent catastrophic failures of tailings dams worldwide.

• These events have focused industry attention on the importance of developing and implementing effective monitoring strategies on all mine sites.
Satellite Radar Interferometry

A remote sensing technique capable of identifying and measuring ground deformation widely adopted in slope stability assessment and monitoring globally.
Using data from radar satellites the first deformation maps were produced in 1992 to measure the effects on an earthquake.

InSAR technology has rapidly advanced to become a remote sensing technique for measuring ground deformation.

Uses high-resolution sensors, with automatic, robust and scalable processing algorithms.
Basic Deformation Maps

Visibility Analysis

Change Detection Analysis

DInSAR and RMT Analyses

Contour map of recent deformation
SqueeSAR® Technology

- Requires 15+ images.
- Identify point targets on the ground.
- No instrumentation or site access required.
- Removal of:
  - Atmospheric Noise
  - Topographic Noise
- Produces high-density point cloud of measurements.
- Every point has a time-series of deformation.
InSAR Measurements (SqueeSAR)

- Each measurement point has an associated time-series.
- Maps typically have thousands of points.

**SqueeSAR 1D Analysis (Line of Sight) with TSX Spotlight**
Vertical and Horizontal East-West Decomposition

» SAR satellites navigate along near-polar orbits - sensitive to surface change occurring along a line-of-sight (LOS).
  • Basic InSAR measurements are a one-dimensional (1D).
  • Single geometry may miss steep slopes on one side of a pit.

» Combining the Earth’s rotation with satellite orbital paths captures the Earth’s surface in two satellite geometries (2D).
  • Ascending (or east-looking)
  • Descending (or west-looking)
Combining Ascending and Descending data sets:

» Maximises the coverage of ground features, especially in areas with strong topography.

» Simplifies the interpretation of InSAR results by providing true vertical and horizontal east-west data instead of simple LOS measurements.

» Enhances the integrability of InSAR data with geotechnical sensors, Automatic Total Stations (ATS), levelling, GNSS and slope stability radars.
2D Analysis Maps

LOS Ascending

LOS Descending

Vertical

E-W Horizontal

2D
East-West Cross Section
SATELLITE RADAR SENSORS
High resolution and Medium Resolution
• More than 15 satellite options with different frequencies, spatial resolutions, orbits and revisit times.
• New satellites are being set in orbit to replace older generations.
• Additional satellites are being added to existing constellations.
• New constellations are scheduled to take orbit in the near future.
Sentinel vs COSMO-SkyMed – Waste Piles
A RECENT CASE STUDY

Xinjing Mine Slope Failure
Scores missing after large mine collapse in China

By Nicholas Yong and Fiona Ní Níomháin

At least four people have died and 32 others are missing after a mine collapsed in China's northern Inner Mongolia region on Wednesday.

Chinese leader Xi Jinping ordered a search and rescue operation which has so far found six survivors in the open pit mine in the Inner Mongolia region.
Sentinel-1 Results

Linear displacement

Acceleration in January 2022
MONITORING WITH INSAR: A REAL PERSPECTIVE
• Higher frequency of observations will make InSAR monitoring programs even more effective for rapid decision making.

• Continuous improvement of machine-learning algorithms such that users have the ability to take advantage of present and past data to predict future trends based on probabilistic geotechnical models.
Today’s InSAR services and tools used in mining:

- Identifying slope instabilities and associated risks
- Mapping & measuring subsidence
- Identification of active faults
- Monitoring block caving induced subsidence
- Monitoring TSF integrity

- Fully remote monitoring service using improved satellite constellations.
- Provides a site-wide bird’s eye view of surface deformation over multiple assets.
- Complements other monitoring methods and easy to integrate in data integration platforms.
InSAR Monitoring Services on TREMAPS

- Displacement updates with every new acquisition.
- Time-series of deformation describing the evolution of surface displacement in terms of velocity, acceleration or seasonality.
- Potential updates up to every 2 days (in the future) using a variety of constellations acquiring simultaneously.
InSAR technology for mining activities
SqueeSAR [mm]
InSAR technology for mining activities
Rapid Motion Tracking [dm - m]
InSAR technology for mining activities

InSAR Bulletin [cm - dm]
EXAMPLE OF CURRENT SERVICE

Continuous Monitoring over TREMAPS Portal
• Web portal to distribute our data and provide some analysis tools to the clients

• Easy to access to several operators or working groups related to a single mine area i.e. (mine managers, Geotech, surveyors)

• The data can be downloaded to use in GIS systems
TREMAPS: toward a dynamic use of our data
Dynamic use of our data: TREMAPS
Dynamic use of our data: TREMAPS
Collaborating with other monitoring service providers to ensure data products can be merged and integrated in other platforms.

Working with clients to better understand their needs and requirement.

Continuous development of new processes and tools to help users get the most out of our products.
Effective monitoring programs:

- **Visualization**: Data screening tools.
- **Trend Detection**: Identification of relevant surface movement trends
- **Rapid Updates**: weekly (current) or even every day or few hours (in the future).

**Our goals**

**Client’s goals**

- Receive timely information
- Enable geotechnical and mine management to:
  - **Improve** strategic decision-making
  - **Optimize** operations
  - **Reduce** potential hazards
Who We Are

~5,000,000 km² analysed everywhere in the world

1mm PRECISION on single displacement measurements

SAR satellites PAST AND PRESENT
Ready for future platforms

600+ InSAR PROJECTS in different market sectors

International PATENTS on radar data processing

SqueeSAR® DespecKS® Double-Geometry Corner Reflectors

20 YEARS EXPERIENCE

120,000 Satellite Radar IMAGES PROCESSED
InSAR Technology Basics

INTERFEROMETRY

- Wavelength:
  - C-band = 5.66 [cm]
  - X-band = 3.10 [cm]
  - L-band = 24.00 [cm]
Derivative Maps

2D Velocity

Vertical

E-W Horizontal

2D Acceleration

Vertical

E-W Horizontal
Date of failure: 22/02/2023

Sentinel-1 – Track 157 Ascending was the **best option** among other Tracks covering the area

- Unfortunately, Track 157 stop the acquisition 15/11/2022
- Furthermore, between the 13/04/2022 and the 15/11/2022, Sentinel-1 acquired only 4 images (less than 1 image/month)
Sentinel-1 Results
Comparing Spatial Resolution

- A comparison of SNT and TSX at over mine assets at the same scale.
- Green scale bars are all 100m.
- SNT: Shows a general picture of the surface deformation.
- TSX offers more detailed characterization, and better contouring of the deformation affecting the structures.
Perspectives on the prediction of catastrophic slope failures from satellite InSAR

Tommaso Carli, Emanuele Intieri — Nicolas Casagli

www.nature.com/collections/agegihhehi
The number of SAR data sources is increasing steadily:

- Growing demand for earth observation (EO) data.
- Reduced cost in manufacturing, launches & operation.
- Increasing demand from the private sector.
- Applications evolution from Intelligence & Security to Institutional Projects to Commercial Applications.
- Complementary to optical image without susceptibility to cloud cover.
- Increasing interest from investors despite a high-risk factor still associated with the aerospace sector.
The Trend is Clear

The near future will see several new constellations of EO satellites operated by private companies.

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Data redundancy:
- Numerous smaller & less expensive sensors.
- Reduced risk in service interruption or failure.
- Satellite sensors easily added, replaced or upgraded.

High-resolution and short revisit cycles:
- High spatial resolution (<1 m).
- Very short revisiting time.
- Daily acquisitions as the new standard.
- Possibility to increase up to 3–4 images/day.