Curtin University of Technology

Integration of InSAR and GIS for Monitoring of Subsidence Induced by Block-caving Mining

by

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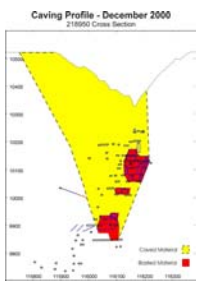
Introduction

- Knowledge of surface subsidence, induced by underground mining, is an important factor that significantly helps to develop an accurate deformation model of rock strata:
  - ➢ Predicting future deformation
  - ➢ Detecting stress field in the rock mass above a mining extraction region.

Research Site

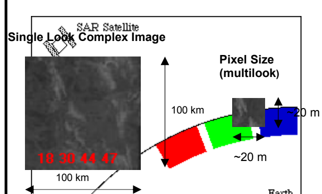


Mining Deformations

Deformation Monitoring Systems

- Surveying techniques
  - ➢ Levels, theodolites, total stations, GPS receivers and photogrammetric cameras
- Geotechnical methods
  - ➢ Crack measuring pins, extensometers, inclinometers, piezometers, tilt-meters and microseismic geophones
- Remote sensing?
  - ➢ Airborne, space-borne (SAR = synthetic aperture radar)

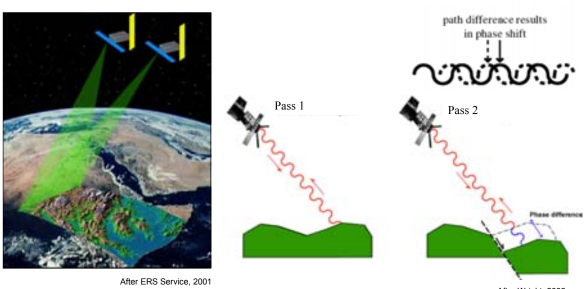
Synthetic Aperture Radar (SAR)



(After the Alaska SAR Facility's Homepage)

- An antenna that emits a short electromagnetic (radar) pulses in a specific direction,
- A receiving antenna that detect the backscattered signal with directional precision,
- A clock that measures the time delay between emission and detection,
- A scanning system that allows to scan the surface of the earth with the directional beam and to determine a direction and range to a target.

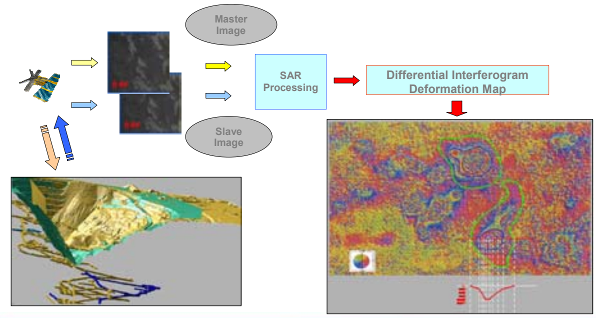
What is InSAR ?

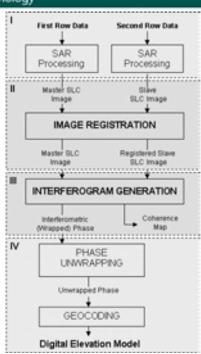


After ERS Service, 2001

After Wright, 2002

InSAR Based Deformation Monitoring





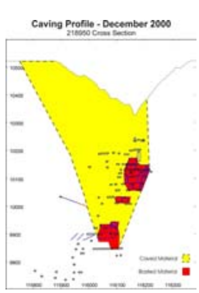
InSAR Processing

(After the Alaska SAR Facility's Homepage)

InSAR Technique Characteristics and Limitations

- InSAR can deliver continues coverage and accuracies that are compatible or exceed capabilities of classical surveys,
- InSAR does not require any field instrumentation and consequently results in significantly reduction of the costs of monitoring and interpretation process,
- allows the monitoring of hazardous and inaccessible area, as the method requires little ground-based monitoring to calibrate the results,
- provides data with high vertical accuracy, **(?)**
- works under different atmospheric condition and **(?)**
- easy links to the GIS environment.
- Poor temporal resolution (limited satellite coverage)
- Coherence problem caused by vegetation effect
- Phase errors due to the processing (eg. unwrapping related errors)
- The InSAR processing software has a high level of complexity and requires relatively long time to be understood and mastered.

Case Study – SLC in Western Australia



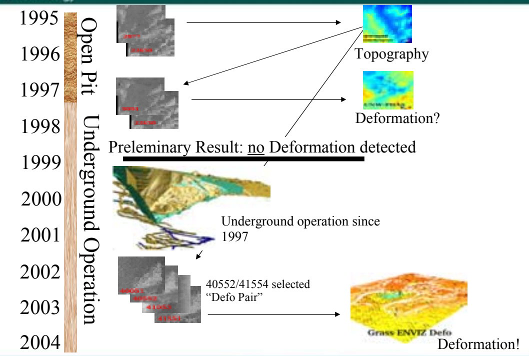
Project Objectives

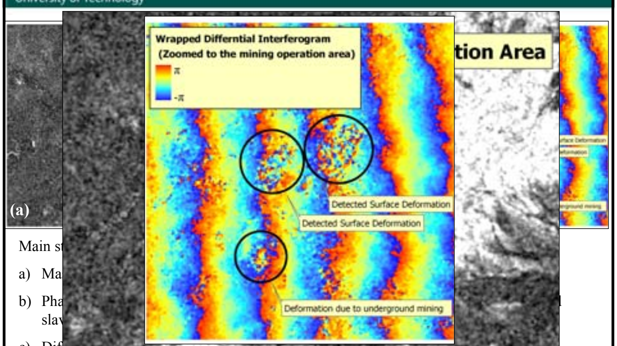
- To use differential interferometry techniques to produce an interferogram of subsidence which will allow to predict possible failures
- To analyse and validate generated interferograms in terms of surface change
- To compare InSAR results with those obtained via traditional surveying methods
- To determine a minimum area of deformed surface that the InSAR technology can detect
- To use GIS as a value-adding tool in order to post-process, interpret and assimilate disparate InSAR results.

Selected SLC Frames

No.	Frame	Orbit	Baseline	Satellite	Date
Topo-Pair					
1	4164	22650	0	ERS1	1995-11-14
2	4164	2977	515	ERS2	1995-11-15
Defo-Pair based on (1)					
3	4164	9991	-199	ERS2	1997-03-19
Defo-Pairs based on (4)					
4	4167	40051	0	ERS2	2002-12-18
5	4167	40552	1274	ERS2	2003-01-22
6	4167	41053	842	ERS2	2003-02-26
7	4167	41554	n.a.	ERS2	2003-04-02

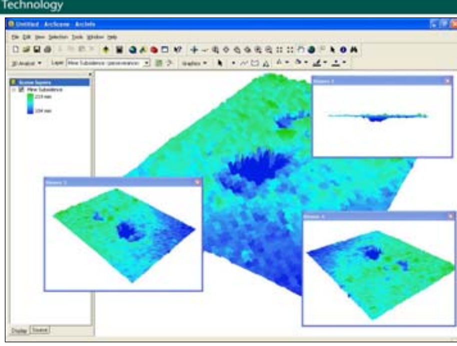
- Frames 1 & 2 (tandem) >> create DEM
- Frames 1 & 3 …4,5,6,7 >> create differential interferograms



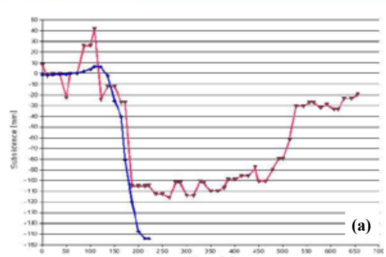


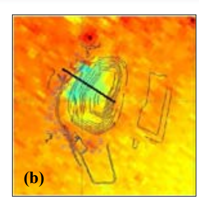
Detected subsidence over the underground mining operation.

(Final result after phase unwrapping and slant to height conversion processes)



3D views of mining subsidence





a) Comparison of subsidence "Measured vs. InSAR",
b) Position of "subsidence" cross-section

Conclusion

- The InSAR capability of making many thousands of accurate measurements over small areas, and GIS ability to handle, analyse and model spatial data, offers detailed analysis of the deformation mechanism.
- The initial results, presented in this paper, confirm the applicability of the InSAR technology for monitoring mine subsidence at significantly low cost and high accuracy.
- With respect to the availability of weekly or daily InSAR data with global coverage in near future, the technique could play an important role in development of supplementary or alternative mine subsidence mapping method.

Conclusion (con'd)

Specific modifications are necessary for utilising the technique in mining context. Limitations such as followings, are restricting the potential of this technology to monitor mine related deformation:

1) difficulty to resolve deformation with high gradient changes,

2) difficulty to retrieve the deformation rates for localised deformation and

3) the lack of SAR images with required specifications.

Future Studies

- To improve current InSAR capability, with respect to the characteristics of mining-induced deformation
- To apply the GIS-based solutions, in specific, deformation trend analysis and spatial modeling for validating and tuning InSAR results during next phases of the research
- To produce training datasets for under-progressed numerical models of surface deformation

Acknowledgments

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- The European space agency's (ESA) ERS-1 and ERS-2 satellites have been used to collect the interferometry data. The data were obtained as a part of ESA cat-1 project (no.1123).
- The interferometry processing in this project was performed using the freely available Doris software, developed by the delft institute for earth-oriented space research (DEOS), delft university of technology (http://www.geo.tudelft.nl/doris.html) and the demo version of EarthView software (EV-InSAR) from Atlantis scientific inc., Canada.