InSAR Operational and Processing Steps for DEM Generation

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Digital Elevation Model (DEM)

- Digital Elevation Models (DEMs) are used in many applications in the context of earth sciences:
  - Topographic mapping,
  - Environmental modelling,
  - Rainfall-runoff studies,
  - Watershed management
  - Coastal management
  - Landslide hazard zonation
  - Seismic source modelling
  - etc

Problems Traditional Methods

- Problem of optical imagery in tropical areas like Nigeria is cloud cover
- Most of the traditional methods are point-based measurement techniques
- Too costly if a very large area needs to be mapped.
- Many traditional methods require accessibility to the site and a personnel must man the instrument.

InSAR

- Powerful tool in mapping surface topography with high accuracy and fine resolution over a wide area.
- Active sensor.
- Operates in all weather day and night.
- Difficult or impossible and costly to obtain by conventional geodetic methods

InSAR cont.

- Also capability to provide inexpensive, holistic and timely maps of surface deformation hazards:
  - Ground subsidence due to water and hydrocarbon extraction
  - Subsidence in mining areas
  - Urban deformation
  - Landslides (displacements from mm/year to cm/day)
  - Surface deformation in volcanic zones
  - Co-and post-seismic deformations.

Problem of InSAR Processing

- Classical InSAR processing is known to be computationally laborious.
- The amount of data to be handled is enormous (*A typical scene of ERS data for instance s occupies about 650 Megabytes of computer storage).*
- The input data often expensive.
- The data quality a priori unknown.
- Algorithms require fast computers.
- For each selected image pair several pre-processing steps have to be performed.

Ideal InSAR Processing scenario

- DEMs can be generated on an operational basis.
- Similar to the case of Photogrammetry and optical remote sensing.
- Optimised in a well articulated processing steps and organisational workflow.
- Important for commercial exploitation of satellite InSAR data, and for scientific investigations.

7

This Paper describes InSAR processing steps that will:

- Implement an approach for organising the sequence of image processing steps
- Minimise disk access, RAM access, and image cache size.
- Support and take full advantage of low-cost computing hardware (e.g., PC Pentium)
- Take advantage of the best of the open source software

8

Proposed InSAR Processing Work Flow

Data Search → Data Processing → Product Validation

9

Mission	SEASAT	Jers-1	ERS-1	ERS-2	Envisat	Radarsat1
Owner	JPL	Japan	ESA	ESA	ESA	CSA
Launch date	June 07, 1978	Feb. 11, 1992	July 16, 1991	April 20, 1995	2002	1995
Ended date	Oct '10, 1978	Oct' 12, 1998	2000			
Band	L(23.5 cm, 1.275 GHZ	L(23.5 cm, 1.275 GHZ)	C(5.7 cm, 5.25 GHZ)	C(5.7 cm, 5.25 GHZ)	C(5.7 cm, 5.25 GHZ)	C(5.7 cm, 5.35 GHZ)
Polarization	HH	HH	Vv	Vv	all	vv
Look angle	20 (23)	35 (35)				
Swath	100km	75	100	100	50-400	45-500
Range Resolution	25	18	20	20	20	10-100m
Azimuth Resolution	25	18	30	30	30	10-100m
Left/Right Looking	Right	Right	Right	Right	Right	Right
Looks	4	3	4	4	4	
Orbits	Altitude: 800 km in near polar orbit	Altitude: 568km, inclination: 98 degrees	Altitude: 785km, inclination 98.5 degrees	Altitude: 785km, inclination 98.5 degrees	Altitude: 785km, inclination 98.5 degrees	Altitude: 785km, inclination 98.5 degrees

10

Problem of Temporal Decorrelation

Procedures to minimize data quality risks:

- Assessment of topography, climate and weather conditions during the SAR acquisitions.
- Assessment of the impact of seasonal vegetation cover on temporal decorrelation, based on World Wide AVHRR NDVI mosaics.
- ERS Interferometric Quick Look processor developed by ESA http://earth1.esrin.esa.it/INSI.

11

Data Processing

Data Pre-Processing → Co-registration and resampling → Computation of Interferogram → Phase Unwrapping → Geocoding

12

Delft Object-oriented Interferometric Software (Doris)

- Fully functional interferometric processing software in the public domain.
- Each tool on Doris performs a single, well-defined function
- ***Getorb*** to obtain precise orbital data records for the ERS satellites
- ***SNAPHU*** for phase unwrapping
- ***GMT*** for general plotting and gridding
- ***PROJ.4*** for coordinate transformations

Data pre-processing step

- Data input, data cropping, and oversampling
- Input of both master and slave data sets for the InSAR processing (Only Single Look Complex (SLC) data are processed).
- Orbit data downloaded from the ***Getorb*** website for the computation of precise orbit are also read.
- Doris then reads the SLC leader, volume and header data file as well as relevant parameters.
- Oversampling of data in range and azimuth direction, and amplitude calibration are also performed in this step.

Co-registration and resampling step

- **Determination of co-registration polynomial that describes the transformation of the slave to master image, which is subsequently used for the resampling of slave image to the master grid.**

Computation of Interferometric Products step

- Complex interferogram and the coherence image are generated.
- The interferogram is the dot product of the master and complex conjugated slave, i.e., it contains the product of the amplitudes and the difference of the phases of master and (aligned) slave.
- The phase difference contains information on topography, possible deformation, and possibly atmosphere.
- Coherence image is also computed in this step.

Phase Unwrapping step

- **This is the reconstruction of the original phase from the wrapped phase representation.**
- **The Statistical-Cost, Network-Flow Algorithm for Phase Unwrapping (*SNAPHU*) phase unwrapping software is called by Doris for the phase unwrapping computations**
- ***SNAPHU* can be downloaded Web site of the Stanford University.**

Geocoding step

- **In this step the unwrapped phase is converted to a height, and the (azimuth, range) coordinates are geo-referenced.**
- **These output matrices are also gridded using the *GMT* tools.**
- ***PROJ.4* performs coordinate transformations to obtain the DEM in the desired coordinate system.**

Product validation stage

- This stage includes all aspect of quality assessment of the InSAR products through comparison with reference models obtained from independent sources.

19

Processing Bam Iran ENVISAT Data Sets

Image Parameters	Master	Slave
Frame number	22	23
Orbit number	9192	9693
Acquisition date	03-Dec-2003	07-Jan-2004
Acquisition Time [UTC]	06:13	06:13
Number of lines	26897	26580
Number of range pixels	5167	5167
Radar wavelength (m)	0.0562356	0.0562356
Sensor Platform Mission Identifier	ENVISAT-ASAR-SLC	ENVISAT-ASAR-SLC
Product Type	ASAR	ASAR

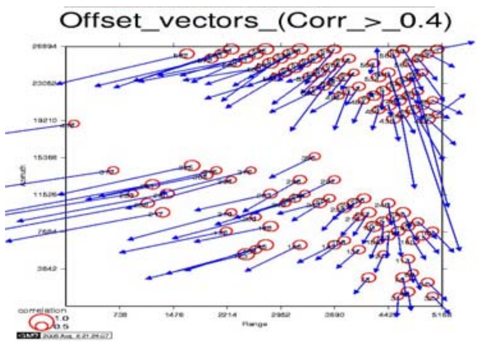
20

Product Parameters

Product Parameters	Value
Scene size [km]	100 x100
Scene center longitude [deg]	58.5219
Scene center latitude [deg]	29.1385
Perpendicular baseline [m]	520.6
Parallel baseline [m]	269.1
Height ambiguity [m]	15.1
Temporal baseline [day]	35
Base line orientation [deg]	-7.1
Look angle [deg]	20.1
Incidence angle [deg]	22.8

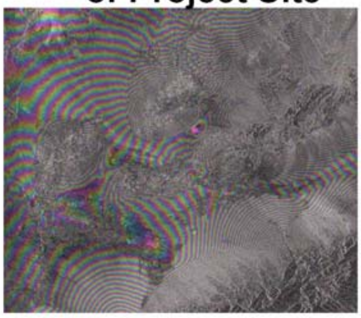
21

The estimated offsets for co-registration

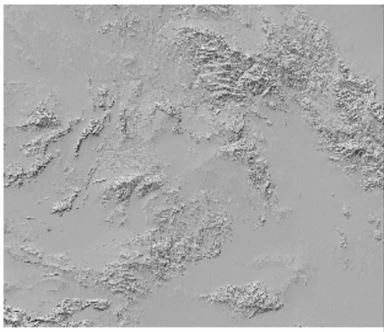


22

Topography Interferogram of Project Site



DEM of Project site Depicted with MicroDEM Software



24

Conclusion

- The InSAR processing steps described in this work can be adapted to form a data processing workflow for an organisation, and for scientific investigation.
- Practical application of the InSAR processing steps described in this paper has been tested with the processing of the Bam Iran ENVISAT ASAR data set to yield DEM of the area

25

Thank you very much for listening

26