Synthetic Aperture Radar

Land Applications

III A

Answers to the theory section (I)

prepared by

Introduction

This SAR Land Applications Tutorial has three main components:

I. Background and theory - an overview of the principles behind SAR remote sensing, data processing techniques, examples of land applications, and current and future sources of SAR data. This includes questions to test student understanding of the material.

II. This Bilko Exercise - providing hands-on experience in the processing and interpretation of alternating polarisation (AP) data from Enivsat-ASAR.

III. Answers

This section (III A) provides model answers to questions from the theory section. Section III B (in a separate document) gives answers and screenshots for the Bilko exercise

The answers complement the other components of the tutorial, allowing the user to check their own understanding.

Content

- Answers to questions in section 1 – what is SAR?
- Answers to questions in section 2 – SAR products.

Content – Answers to questions in section 1

- 1.1 The SAR System
- 1.3 SAR acquisition modes and techniques
- 1.5 Speckle
- 1.6 SAR data statistics
- 1.7 SAR geometry

Theory - 1.1 The SAR System

Answers

A1 : What is the basic difference between real and synthetic aperture radar?

In general the larger the antenna, the more unique information about a particular viewed object can be obtained. With more information, a better image of that object (improved resolution) can be generated. It's prohibitively expensive to place very large radar antennas in space, however, another way to obtain fine resolution has been developed: the spacecraft's motion and advanced signal processing techniques to simulate a larger antenna is used.

A2 : What does synthetic aperture mean?

A SAR antenna transmits radar pulses very rapidly. In fact, the SAR is generally able to transmit several hundred pulses while the spacecraft passes over a particular object. Many backscattered radar responses are therefore obtained for that object. After intensive signal processing, all of those responses can be processed in a such a way, that the resulting image looks like the data were obtained from a big, stationary antenna. The synthetic aperture in this case, therefore, is the distance travelled by the spacecraft while the radar antenna collected information about the object.

Theory - 1.1 The SAR System

Answers (cont.)

A3 : What advantages does SAR have over Optical and Lidar systems?

Radar employs radio waves. When radar is selected from these possible choices, the decision is usually based upon radar's independence of solar illumination and weather conditions. Furthermore, the most advanced SAR systems have the capability to acquire polarimetric and interferometric data, hence enabling to collect polarimetric and interferometric phase information. This is unique to SAR systems.

Theory - 1.3 SAR Acquisition Modes and Techniques

Answers

A1 : What is the most common used acquisition mode?

The most common used acquisition mode is the Stripmap one.

A2 : Which mode, and why, enables the collection of very high resolution images?

The Spotlight is the mode that gives the highest spatial resolution, since the sensor steers its antenna beam continuously illuminating the terrain patch that is imaged.

A3 : What is the importance of interferometric phase?

SAR interferometry exploits the phase measurements to infer differential range and range change in two or more complex-valued SAR images of the same surface, thereby deriving more information about an object than is obtainable with one single image.

A4 : What is the advantage of SAR polarimetric sensors with respect to conventional SAR systems?

Amplitude, phase, frequency, and polarization parameters describe the characteristics of an electromagnetic wave. The main advantage of polarimetry is that it gives a better understanding of the radar wave/scattering medium interaction.

Theory - 1.5 Speckle

Answers

A1 : Why are optical images not affected by speckle?

Because sun light is not coherent.

A2 : Identify an instrument (apart from SAR) which data are affected by speckle.

Laser instruments are also affected by speckle, because they are coherent systems.

Theory - 1.6 SAR Data Statistics

Answers

A1 : What is the difference between Power and Intensity data?

There is no difference.

A2 : How are Intensity data are calculated from SLC data?

Intensity = real^2 + imaginary^2 . The distribution is negative exponential.

A3 : How are Amplitude data calculated from SLC data? What is the data distribution?

Amplitude = sqrt(Intensity). The data are Rayleigh distributed.

A4 : How is phase calculated from SLC data? What is the data distribution?

Phase = inverse tangent (imaginary/real). The data are uniformly distributed over the range $-\pi$ to $+\pi$.

Theory - 1.7 SAR Geometry

Answers

A1 : Explain the difference between slant and ground projection.

Slant range is the original projection (slant range plane), where the SAR data are acquired. Ground range is a hybrid projection (which should be avoided), where the SAR data is projected according to 1/sin (incidence angle). Note that ground range data are not to be confused with geocoded data.

A2 : Why should slant range projection be used for the geocoding process?

Because the slant range projection, which is the original SAR geometry, is straightforward related to the geocoded data through the range-Doppler function.

Theory - 1.7 SAR Geometry

Answers

A3 : What is the difference between slant range pixel spacing and ground resolution?

The slant range pixel spacing (SRps) is the pixel size that the SAR data have been sampled during the focusing step. Ground resolution (Gr) is the resolution of the data projected into the Earth. The relationship is given by Gr= SRps / sin (incidence angle).

A4 : What is the difference between layover and foreshortening?

Layover is the extreme case of foreshortening, e.g. where the range distance, instead to increase, decreases.

Content – Answers to questions in section 2

- 2.1.1 Focusing
- 2.1.2 Multi-looking
- 2.1.3 Co-registration
- 2.1.4 Speckle filtering
- 2.1.7 Geocoding
- 2.1.8 Radiometric calibration
- 2.1.11 Classification
- 2.2.1 Interferogram generation
- 2.2.3 Interferometric correlation (coherence)
- 2.2.7 Phase to displacement conversion

Theory - 2.1.1 Focusing

Answers

A1 : Assuming that the orbit is not stable (as in the airborne case), what should be considered during the focusing step? Assuming that a standard (as presented) focusing would be used, how would looks like a SAR image?

During the focusing step motions of the aircraft (which results from the atmospheric turbulence) must be additionally considered. This specific focusing step is known as motion compensation. Assuming that a standard (e.g. spaceborne) focusing would be used, the SAR image would appear, in presence of turbulence, blurred. Furthermore, the location of the pixels in the slant range geometry would be obviously wrong.

Theory - 2.1.2 Multi-looking

Solution

1. SLC data are in complex format, while Power data are real data. The conversion from SLC to Power data is performed as follows:

   - Power = real*real + imaginary*imaginary
   - Amplitude is the square root of Power

2. The appropriate multi-looking factors are 1 look in range and 4 looks in azimuth.

   These factors have been calculated as follows:

   -> ground resolution = 7.8m / sin(38) = 12.66m
   -> resulting pixel spacing azimuth = 3.2m x 4 =12.8m

Theory - 2.1.3 Co-registration

Answers

A1 : Can SAR images acquired with different acquisition geometries or sensors be co-registered? Explain your answer.

Definitely no. Images must be acquired with the same acquisition geometry, because, essentially, co-registration is a shift in x-, and y-direction in slant or ground range geometry. Hence different geometries (due to different acquisition modes or different sensors) disables the execution of this step.

A2 : What is the difference between co-registered and geocoded images?

Geocoding (based on range-Doppler equations) - e.g. the process to transform SAR data from slant or ground range projection into a cartographic reference system - is the only way to overlap images acquired with different acquisition geometries or from different sensors. Co-registration only enables the overlapping in slant or ground range projection of SAR images acquired in the same acquisition mode.

Theory - 2.1.4 Speckle Filtering

Answer

A1 : What are the basic differences between mean or median filters and a conventional (for instance Lee or Frost) speckle filter?

Both types of filter use a moving window. The main difference between non-speckle specific and speckle specific filters (such as Lee, Frost, etc.) is that the speckle specific filters usually includes a multiplicative model and the use of the local statistics. The Frost filter is an adaptive filter, and convolves the pixel values within a fixed size window with an adaptive exponential impulse response. The Lee filter performs a linear combination of the observed intensity and the local average intensity value within the fixed window.

Theory - 2.1.7 Geocoding

Solution

Part 1

If a SAR geocoding algorithm is not available, two possible solutions (which, in both cases, will not provide accurate results) are proposed.

Solution 1: the slant range data are transformed into the ground range projection according to the relationship ground range = slant range / sin (incidence angle). In the next step the ground range SAR data are transformed into a cartographic reference system by using an affine transformation based on ground control points.

Solution 2: the slant range data are directly transformed into a cartographic reference system by using an affine transformation based on ground control points.

It has to be pointed out that, in both cases, the results will be inaccurate, due to the non-linearity of the SAR geometry. These inaccuracies are even stronger in the presence of topography. Finally, note that solution 1 will provide better results than solution 2, because the SAR data in ground range projection is less distorted than the slant range one.

Theory - 2.1.7 Geocoding

Solution (cont.)

Part 2

If a SAR geocoding algorithm is available, the following data and parameters are requested:

Data

- Digital Elevation Model
- Satellite positions and velocities. The orbital data are already provided with the SAR data.

Parameters

- Cartographic parameters, such as projection and ellipsoid
- Geodetic parameters, such as datum shift parameters
- SAR processing parameters, which are already provided with the SAR data
- One ground control point to eventually correct the satellite position inaccuracies.

Theory - 2.1.8 Radiometric Calibration

Answers

A1 : What do you need, in terms of data, in order to perform a correct radiometric calibration?

Besides the SAR data (preferably in slant range projection), a Digital Elevation Model, having an original resolution at least comparable to that of the SAR image is requested. It assumed that information on the Antenna Gain Pattern is provided with the SAR data.

A2 : Assuming that an ellipsoidal geocoded, but not radiometrically calibrated image is available. What can you do in order to calibrate the SAR data?

A radiometric calibration is no longer possible once the SAR data have been geocoded. In fact, a rigorous radiometric calibration must be performed during the geocoding step, because all orbital and DEM data must be considered.

Theory - 2.1.11 Classification

Solution

A simple, but in this case, efficient solution, is to perform a ratio between image 1 (HH polarisation) and image 2 (HH), and subsequently between image 2 (HH) and image 3 (HH). The same is executed for the HV-polarisation images. In this way, the land cover changes between the different acquisitions can be detected.

Once that the four ratio images are generated, it is possible, using a simple parallelepiped classifier (e.g. data thresholding), to classify the changes in classes, which, in this case, will correspond to the rice fields.

Theory - 2.2.1 Interferogram Generation

Answers

A1 : Is it possible to generate an interferogram between two ASAR images acquired with different incidence angles?

No, because the two images have a different geometry.

Theory - 2.2.3 Interferometric Correlation (Coherence)

Answers

A1 : Which parameters strongly affect the Coherence values in the repeat-pass case?

Three main parameters affect the Coherence values, as they reduce the correlation values.

- The baseline - a large baselines induces decorrelation,
- temporal changes of the object on the ground (for instance phenological changes), and
- temporal changes due to the effect of meteorological events (for instance dry and wet conditions due to precipitation).

A2 : In which land applications could the use of Coherence be of importance ?

Coherence plays an important role in the detection of temporal land cover changes, in particular in dry areas, and for urban mapping.

Theory - 2.2.7 Phase to Displacement Conversion

Answers

A1 : What are the pros and cons of DInSAR using C- and L-band data?

C-band has a wavelength of approximately 5 cm, while L-band around 23 cm. In general, for slow movements, C-band may be more accurate than L-band, due to the shorter wavelength. On the other hand, L-band data is more robust (less temporal decorrelation due to the longer wavelength) than C-band in particular in vegetated areas.