Doris: the Delft Object-oriented Radar Interferometric Software

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ABSTRACT

The new InSAR processing software Doris (Delft Object-oriented Radar Interferometric Software) is presented, which is currently under development at the Delft University of Technology. It is written entirely in C++ and has a modular structure. Each module identifies a different algorithm for a processing step. The user can select those modules that best suit his needs for a certain interferometric application. The flexibility of a modular design also permits easy updating of the software, without affecting the general structure of the program. The software is being developed at a HP-Unix machine, though it is intended to make it portable to other platforms.
The current, first version (v1.0) of Doris is capable of processing single look complex (SLC) images to the basic interferometric products. New routines are now being added to extend the processing to the generation of the final products, e.g., digital elevation models and deformation maps.

1. INTRODUCTION

Since 1995 the InSAR group of DEOS is interested in the application of InSAR for the detection of surface deformations with sub-centimeter accuracy. Research is carried out mainly on the assessment of limitations, such as temporal decorrelation and atmospheric effects, on error propagation studies, and on the validation of results, see for example Usai (1999) or Hanssen et al. (1999). We recognized the need for a flexible, well documented processing tool, because a particular application mostly requires a dedicated algorithm. Therefore, we are currently developing interferometric processing software called Doris. The latest information can be found at www.geo.tudelft.nl/fmr/research/insar/sw/doris.

In this paper we present the first version of the Doris software. The objectives of the software and our developing strategy are presented in section 2. The steps in the interferometric processing and the relations between these steps are identified in section 3, while section 4 describes the state of the art and an example of the processing. Finally, conclusions are given in section 5.

2. BACKGROUND

2.1. Objectives

The main reason for developing our own software is the necessity, when carrying out a research, of knowing the exact implementation specification of the algorithms used in the processing. This is unfortunately not always the case with commercial software, which usually has the drawback of not being completely transparent to the user. For the same reason, it is also often difficult to modify the processing in order to adapt it to specific research purposes. Therefore, in developing the Doris software, we kept in mind the following objectives.

1. It should be easy to incorporate and test new algorithms, without having a specific knowledge of the details of the whole software package.
2. The software should be suited for all the possible applications of SAR interferometry, e.g., generation of digital elevation models, monitoring of deformations and coherence studies.
3. The software should be user-friendly, in terms of interface, but also of speed and of internal and external documentation.
4. The software should be independent of special hardware and software, not platform specific, and have low memory and disk storage requirements. The possibility of parallelization is a future goal.

2.2. Strategy

In order to meet the objectives, we adopted the following strategy. (Note that these points do not exactly correspond to the requirements with the same number.)

1. We selected a modular approach to the processing (which is described in more detail in the next section). In general the output of one processing step is the input for the next, which makes a modular approach attractive. Each method or algorithm within a processing step is regarded as a separate module. Therefore there might be more modules with the same input/output format for a certain step. New modules can be easily added, as long as these formats remain unchanged. Due to the modular approach, it is very easy to select those modules that are best suited to a certain application, e.g., quicklook interferograms, differential interferometry or DEM generation. The first version (v1.0) of Doris has only one module (or a few closely related ones)

for every processing step. Only those steps that are essential to the processing are implemented up to now.

2. As a programming language we selected C++. This object-oriented language is particularly suitable for image processing, such as the interferometric processing. Also the readability of C++ programs is generally better than that of structural languages such as Fortran, which increases the maintainability. This helps the consistency of the software as it is developed by different people. See also Zimmer and Bonz (1996).
3. The input to the software is handled conveniently by means of a small input file. Here the user can select the modules and the proper parameters. The variables that are important to the processing are kept in parameter files. Each SLC image has a file of relevant parameters, and there also is a file for the interferogram. The data output of each module is written to a new file. Although this takes up more disk space than necessary, it makes it easier for developers to debug the software. The internal documentation is done in a structural way, implying that at least the author, the date and a short explanation is given at the start of each routine. The external documentation can be divided in two parts. For the user, we are currently writing a user's manual, and some online helping utilities, such as a short description of the input options and a shell script for running the software. For code developers, there is a document that describes all routines in a more detailed way. This documentation, as well as the source code itself, can be readily converted to html code and viewed with a standard internet browser. This enables new programmers to get a quick overview of the software and facilitates easy navigation between the routines.
4. The software is developed at a HP-Unix platform. The standard libraries are used for portability considerations. The HP MLIB *lapack* and *veclib* libraries are used as well, see HP (1998a) and HP (1998b), because they speed up the computations considerably. This means we are not totally independent, but the code could be adapted to work with other libraries, for example, with a different fast Fourier transformation.

3. LOGICAL DESIGN

In the final version of Doris, the software is intended to cover the entire track from the raw radar and orbit data to the final products. A coarse flow chart is given in figure 1, where the processing is divided in four blocks.

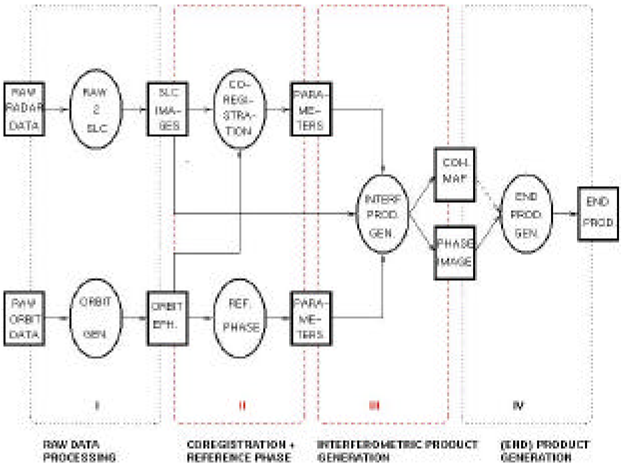

Figure 1: Coarse flow chart of the interferometric processing. Doris v1.0 consists of block II and III.

The first block of the total processing is the raw data processing, see also figure 1. The raw radar data is converted to the SLC format, and the raw orbit data is converted to a more convenient format (we use the Delft Orbital Data Records from DEOS). We plan to include the conversion of the raw radar data to the SLC format in a future version.

The second block of the processing is the coregistration of the images. The transformation model for the alignment of the slave with the master image (within a tenth of a pixel) is computed iteratively. The reference phase, or 'flat Earth correction', is also computed here. A more detailed flow chart of this part of the processing is depicted in figure 2. Notice that not all steps that are identified are required for the processing; a user might choose not to filter the SLC images.

The next part of the processing (block III) is the computation of the coherence map and the phase image or complex interferogram (the interferometric product generation). See figure 3 for a detailed flow chart. The slave image is resampled according to the transformation model, and then multiplied by the master image. The reference phase is subtracted, and multilooking is applied. Optionally the interferometric products may be filtered.

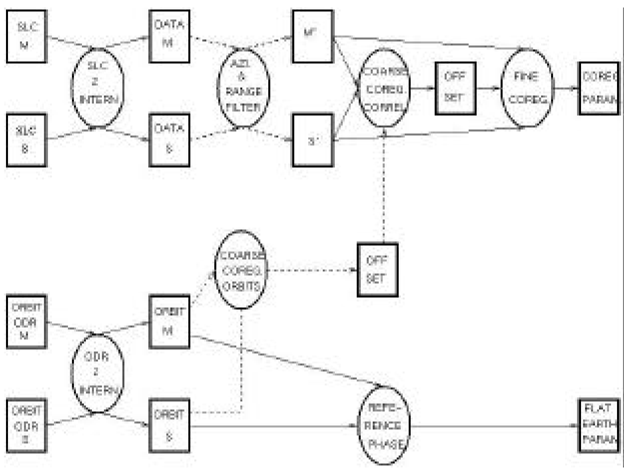

Figure 2: Detailed flow chart of block II of figure 1: the co-registration and reference phase computation.

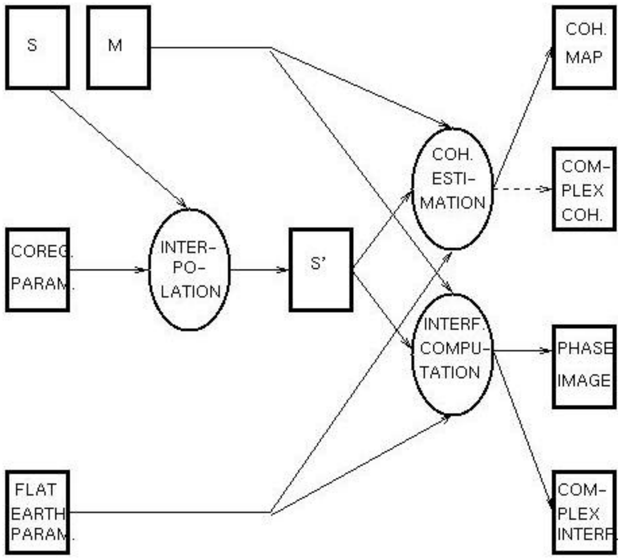

Figure 3: Detailed flow chart of block III of figure 1: the generation of the interferometric products.

Finally, the end products are computed in block IV of the processing.

Figure 4: Location of the test area.

4. STATE OF THE ART

The current version of Doris (v1.0) consists of the generator of the interferometric products, indicated in figure 1 by the blocks II and III. A number of modules are implemented for the steps that are shown in the more detailed figures 2 and 3. The azimuth and range filtering are currently being implemented. The modules that have been implemented are described in, e.g., Geudtner (1996) and Schwäbisch (1995). In the near future, we focus on the completion of all steps of block II, see figure 2, and on the addition of new modules. Simultaneously we will improve the external documentation, as well as continuing the development to the generation of the end products.

4.1. Case Study

In order to show the performance of the software, we have computed the phase image and coherence map for a test area located near Napels (Italy), see figure 4. We selected an ERS Tandem pair (quarter scene). The images (orbit numbers 21066 and 1393, frame 2781) were acquired in July 1995.

The interferometric products are shown in figure 5 and 6. The coherence is quite high, which is to be expected for a Tandem pair and the phase image is in good agreement with the real topography of the area.

The c.p.u. times Doris required are listed in table 1, where only those steps that required a significant amount of time are considered. As one can notice, the resampling (performed in this case with a 16 point truncated sinc) and the generation of the interferometric products are the most time consuming processing steps. The time for the conversion of the SLC data from cd-rom to our internal format is mainly due to the

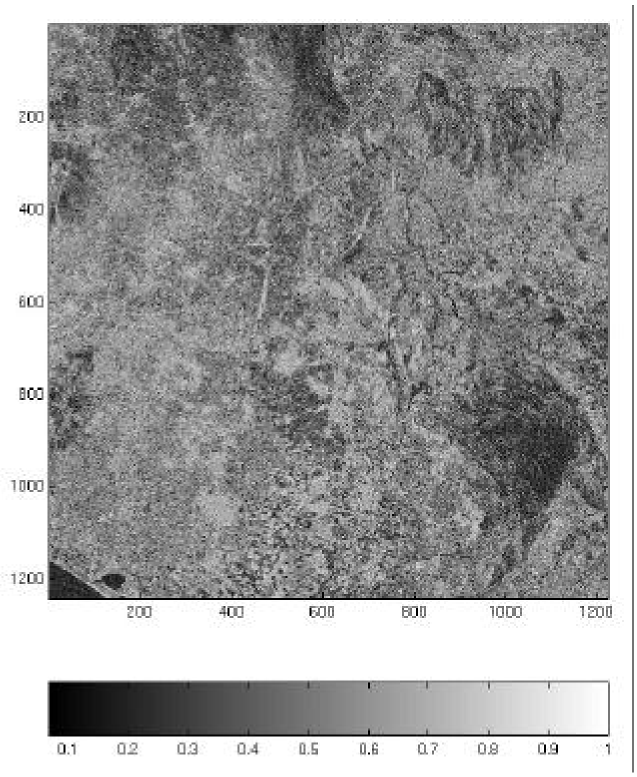

Figure 5: Coherence map of the test area; multilookfactor 10x2; the perpendicular baseline equals 35 m.

buffering we apply (no data is converted, so the use of the c.p.u. is somewhat unexpected). In practice, the limiting factor is the reading speed of the cd-rom.

For comparison, the same pair has also been processed with the commercially available PCI software, see PCI (1997). The same processing options, e.g., for window sizes and interpolation kernel, and the same (precise) orbits have been used, and no filtering has been applied. The interferometric

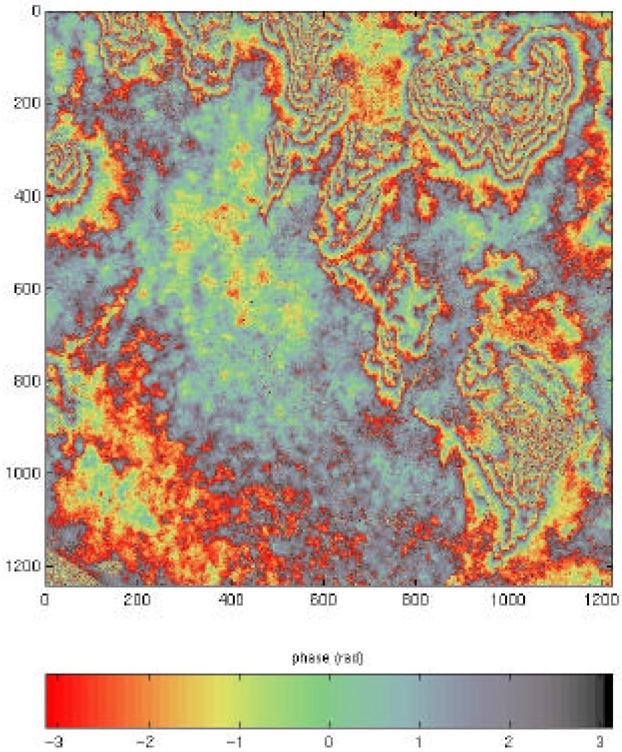

Figure 6: (Wrapped) phase image for the test area; multilookfactor 10x2; the height ambiguity equals 270 m.

	Description	cpu(s)	%
I	Conversion to internal format for master and slave	180	12
II	Fine coregistration	90	6
	Resampling of slave image	790	53
III	Computation of phase image (multi-look window 10x2)	80	5
	Comp. of coherence map (estimation and multilook window 10x2)	330	22
	Total c.p.u.	**1500**	**98**

Table 1. c.p.u. times required by Doris (time consuming steps only). The numbers in the first column refer to the blocks in figure 1.

coherence computed by both software packages is compared in figure 7. The results are in very good agreement, small differences in the histogram being caused by the choice of the bins, and by the slightly different transformation model. As for the phase image, no significant differences were detected. The resampling was the most time consuming step: about one hour processing time.

5. CONCLUSIONS

Doris, a new interferometric SAR processing software, being developed at DEOS, has been presented. The current version of

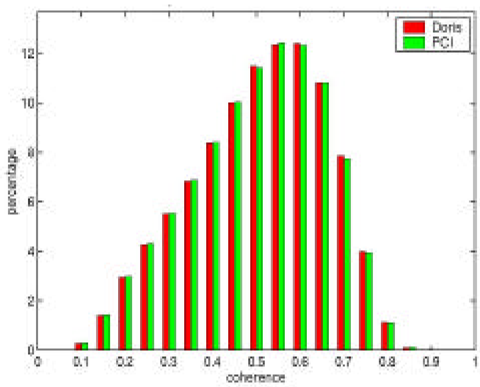

Figure 7: Histogram of coherence for Doris and PCI.

the software produces the basic interferometric products from the SLC images. The performance of Doris has been analyzed both in terms of processing time and quality of results. Future developments include the extension of the processing to the generation of the end products and the implementation of more modules. Furthermore, the technical documentation and a user's manual will be written.

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