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Concept Of An Effective Sentinel-1 Satellite SAR Interferometry System

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Abstract

This brief study introduces a partially working concept being developed at IT4Innovations supercomputer (HPC) facility. This concept consists of several modules that form a whole body of an efficient system for observation of terrain or objects displacements using satellite SAR interferometry (InSAR). A metadata database helps to locate data stored in various storages and to perform basic analyzes. A special database has been designed to describe Sentinel-1 data, on its burst level. Custom Sentinel-1 TOPS processing algorithms allow an injection of coregistered bursts into the database. Once the area of interest is set and basic processing parameters are given, the selected data are merged and processed by the Persistent Scatterers (PS) InSAR method or an optimized Small Baselines (SB) InSAR derivative. Depending on the expected deliverables, the processing results can be post-analyzed using a custom approach, in order to achieve a set of reliable measurement points. Final results can be post-processed and visualized using a custom GIS toolbox, consisting in open-source GIS functionality. The GIS post-processing is enforced by HPC power as well. To demonstrate the practical applicability of the described system, a subsidence area in Konya city, Turkey is used as the study area for Sentinel-1 InSAR evaluation.

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1. Introduction

A new era of SAR interferometry (InSAR) has began since 2014 with the launch of Sentinel-1A. Since April 2016, the second satellite Sentinel-1B completes the Sentinel-1 constellation that will offer interferometric pairs every 6 days (in European and other areas). The huge amount of satellite data calls for forming efficient ways of storage and processing. National facilities, so-called ground segments, are being formed with the view of storing country-wide data. In the Czechia, such task is related to CESNET research e-infrastructure. Another facility, the IT4Innovations, is a modern and continuously updated supercomputer (HPC) in Ostrava, Czech Republic. This facility is prepared to provide a processing power for remote sensing applications, such as InSAR usage for detection of displacements related to for example subsidence or landslides. Both CESNET and IT4Innovations are integrated by a fast access network, allowing a symbiotic technologic environment. This paper presents a partially working concept of an effective fusion of both facilities yielding into a flexible InSAR monitoring system.

2. Sentinel-1 Data Storage and Database (CESNET)

A Sentinel-1 database has been designed to maintain the vast and increasing amount of SAR data available over various sites endangered by terrain deformations. Storage facilities of CESNET are periodically filled by new Sentinel-1 data over predefined regions – they are sorted based on a relative orbit information. Scripts identify separate bursts directly from compressed Sentinel-1 data and extract their metadata into the related database table. The database contains information sufficient to derive look angle vectors needed for a successful evaluation of a real or expected direction of detected displacement.

Overlapping bursts can be coregistered towards a selected burst and corrected by Enhanced Spectral Diversity [8]. This process can be fully automatized using ISCE as the processor [10] or by custom developed algorithms. The advantage of this approach is a dataset ready for both differential and multitemporal InSAR processing. The database is ready to store also processing results when considered effective.

The Sentinel-1 database itself is running as a unique instance of the CESNET Cloud service. Thus the system is easily transferable and backed up. A continuous increase of data storage demands is expected. The database system is flexible in terms of physical existence of data that is referred only as within the path field. At this moment the data storage should be accessible from within the CESNET structure, with the possibility of storage mounting, e.g. using sshfs. Therefore, any storage facility offering a stable and high speed network connection should be usable for extension of the database coverage.

3. Multitemporal InSAR Processing Facility (IT4INNOVATIONS)

The processing facility hosted in IT4Innovations HPC offers both automatized and semi-automatized InSAR processing using well known Persistent Scatterers (PS) and Small Baselines (SB) methods or their derivatives, as implemented in StaMPS [3] and SARPROZ [7]. Results from processing of either software are exported into a file containing information necessary for post-processing and further GIS analyzes and visualization. Activities towards storing the processing results permanently in the database for selected hot-spots are discussed.

3.1. Semi-automatic processing system

The supercomputer facility is using a PBS system for task scheduling. Depending on the complexity of the task, it is possible to schedule a job for one or more computing nodes. A script describing processing chain using Matlab functionality and open-source algorithms from StaMPS and doris tools [5] is passed to the scheduler for processing.

Before the run, user is free to set crucial processing parameters according to the particular interest. The processing chain can be further improved using functions from command line utilities, parallel processing is implemented by a couple of open-source SAR and remote sensing processing projects, including ESA SNAP or Orfeo Toolbox etc. For Sentinel-1 InSAR processing, ISCE can be recommended.

3.2. InSAR Processing using Graphical User Interface

The graphical user interface of an HPC enforced virtual system is particularly useful for a fully supervised InSAR processing. The system is implemented based on [6]. It offers a robust transfer of a virtual system display over the internet. This virtual system is utilizing one node per the registered user. In IT4Innovations, the current main computer cluster Salomon consists of 24 processing cores running at 2.5 GHz frequency, with 128 GB RAM. The key InSAR functionality is based on SARPROZ, allowing a fast and flexible InSAR work flow. The whole graphical user interface (GUI) of the system is named IT4InSAR. It runs on the basis of Debian Linux OS and offers other graphical open-source tools for SAR and remote sensing processing.

3.3. Post-Processing and Visualization of InSAR Results Implemented in IT4InSAR

Both StaMPS and SARPROZ results can be exported into a common formatted text file. This is used as input for a custom post-processing algorithm that uses statistical approaches to identify and remove unwanted outlier measurement points [1]. For visualization purposes as well as further analyzes and post-processing, Geographic Information System (GIS) tools are installed at IT4InSAR GUI. A bridge between outputs from InSAR processing software and the Quantum GIS software package is held by a custom toolbox named RemotWatch Toolbox. Using GIS, empowered by HPC, one may prepare 3-D maps, overlay over available ortophoto maps, visualize PS point time series or a spatial information in the form of spatio-temporal deformation contours or spatial profile plots etc.

Processing results of hot-spot areas stored permanently in the Sentinel-1 (geo)database can be visualized using IT4Innovations VP1 Crisis Map [4] that offers a temporal scaling and additional information, e.g. weather models.

4. Demonstration of System Capabilities in Konya Region, Turkey

Konya Closed Basin is located in the Central Anatolia region of Turkey. The basin covers 7% of the area over Turkey (~55,000 km^2). It has problems with a land subsidence due to groundwater extraction that often leads to a formation of sudden sinkholes. The subsidence is monitored by various scientific works including InSAR [2].

For this demonstration, 46 Sentinel-1A SLC images were achieved covering the period between Oct 2014 until May 2016. Data were downloaded from ESA Scientific Data Hub in the average rate of 15 MB/s. Data were processed directly after their acquisition within the IT4InSAR framework by SARPROZ software, using PS method. Using 23 cores, the subset covering 20 km area (6210x2500 pixels) has been extracted and pre-processed within 1h 40 minutes; the coregistration finished in 65 minutes. The APS (based on 7000 Delaunay graph-based connections) has been estimated in 7 minutes, while the processing of 185 000 pixels by PS method took 50 minutes. The same software has been applied to form small baseline spatially filtered interferograms that were converted for use by StaMPS SB method. The formation of interferograms took around 8 hours, the automatized StaMPS SB processing of 180 000 points then took around 2h 30 minutes (including removal of noisy points).

The results were post-processed for identification of unreliable points [1] and visualized in Quantum GIS. The processing and post-processing outputs are demonstrated in Fig. 1 and Fig. 2. Typical visualization possibilities are shown in Fig. 3. Results were compared to overlapping Cosmo SkyMed dataset results in [2].

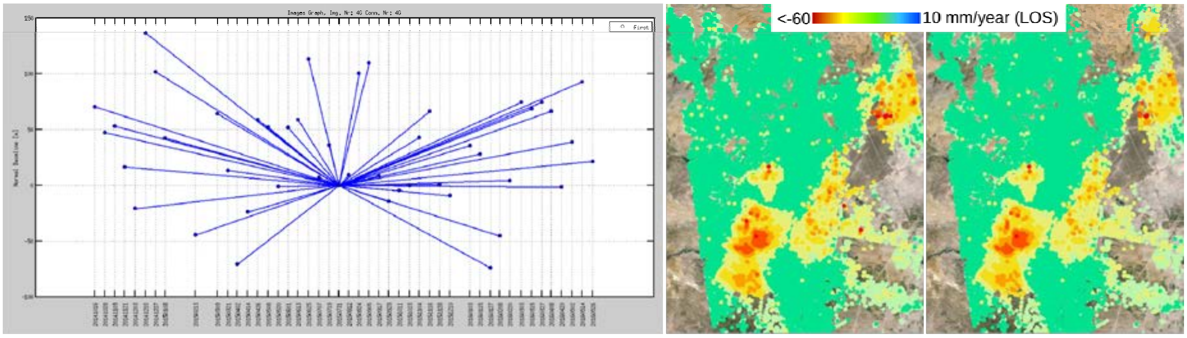

Fig. 1. Processing results of SARPROZ PS: (a) image connections graph; (b) mean velocity result; (c) result after statistical post-processing analysis.

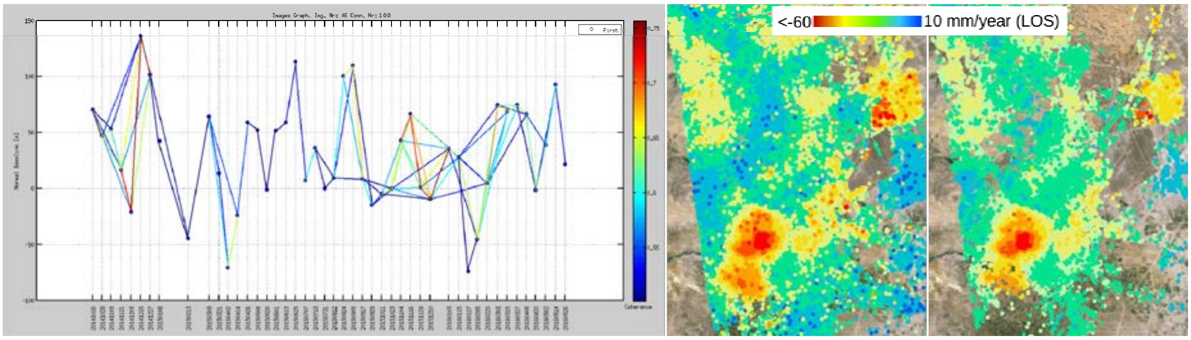

Fig. 2. Processing results of StaMPS SB (based on SARPROZ interferograms): (a) image connections graph; (b) mean velocity result; (c) result after statistical post-processing analysis.

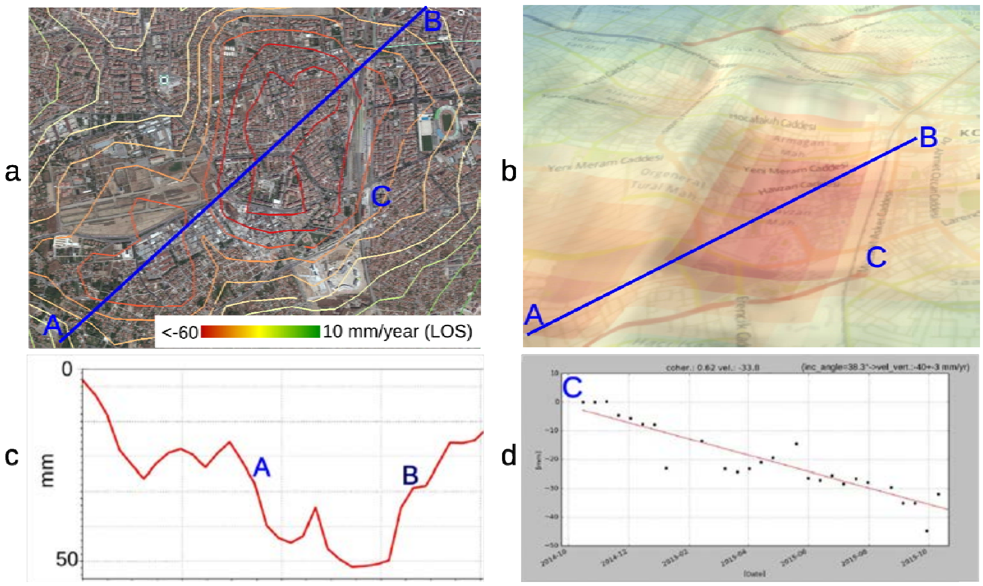

Fig. 3. Different visualization possibilities using Quantum GIS (Qgis RemotWatch toolbox): (a) contour lines of a mean LOS velocity based on interpolated multitemporal InSAR results, layed over an Open Layers ortophotomap (Google); (b) 3-D visualization based on Qgis2threejs tool layed over OpenStreetMaps; (c) a profile plot (Qgis Profile Tool); (d) a PS time series plot (Qgis PS Time Series Viewer tool).

5. Discussion and Conclusions

The current trend applying supercomputers for processing Big Data leads into effective automatized systems. The presented automatized approach has the potential to aid current development trends of InSAR into being a warning tool against dangerous displacements, as e.g. direction of RapidSAR [9] amongst other similar projects. In such cases, identified InSAR hot-spots can have also processing results stored in the database. By storing time series of PS points (over urban areas), one may acknowledge an advantage of a fast reprocessing and a quick addition of a new information after a new image is injected. Similarly to this approach, one may consider an advantage of a short revisit time of Sentinel-1 and form and save spatially filtered short temporal interferograms that can be used to update multi-temporal approaches, such as SB. We believe the concept shows important steps towards a complete and effective InSAR framework utilizing Sentinel-1 data.

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