Statistical learning for Earth deformation monitoring with satellite InSAR

2020 ONERA Ph.D. Proposal

Keywords: Interferometric SAR, Geoscience, statistical signal processing, robust signal processing, optimization.

A. Context & state of the art

Thanks to the Sentinel-1 satellite mission, the European Space Agency (ESA) is able to provide a new SAR image of Europe every 6 days. The availability of such image time-series (ITS) offers an unprecedented opportunity to monitor surface displacement through interferometric SAR (InSAR). On the other hand, developing new algorithms to efficiently process such a huge volume of data represents a current challenge.

Among existing methods, statistical learning approaches have exhibited good performance, as they allow to measure displacements in the order of mm/year. Notably, the phase triangulation based on a maximum likelihood estimator (PTML) [1, 2], allows for obtaining an optimal displacement estimation while exploring all of the dimensions (spatial and temporal) in a SAR image stack. Thus, it provides an appealing mathematical framework that currently drives many recent research works. Indeed, the PTML approach still raises issues that are to be addressed. In this thesis, we aim to tackle two of the major ones:

- **Robust formulation**: The PTML relies on a statistical modeling of the data that has to accurately reflect the empirical distribution. Most studies assume that the observations are Gaussian. However, it is known in SAR imagery that the orbital and/or atmospheric residues, as well as the unmodeled deformation, impose a non-Gaussian noise in the data at high resolution. In this context, the framework of robust estimation [3, 4] is an appealing alternative, as it ensures good performance even in the case of mismodeling. We propose therefore to leverage this framework for developing robust counterparts of the PTML algorithms. This will require to develop optimization algorithms adapted to robust cost functions involving structured parameters (i.e., integrating the physical model of the data), e.g. by adopting the methodology of [5].
- **On-line integration**: The current formulation of the PTML does not allow near-real-time integration of new images acquired gradually over time. The process requires inherently to re-run the whole algorithm at each new incoming image. This is thus computationally expensive in practice and not fully suited to on-line monitoring. Recent works [6] addressed the issue through data compression from mini-batches. However, the current algorithm is neither robust to non-Gaussian observations nor to several temporal decorrelation mechanisms. To cope with these issues, we will also consider an on-line formulation of the robust algorithms that will be developed in this thesis.

B. Work program

In this Ph.D thesis, we propose to develop robust and on-line algorithms for InSAR time-series in the context of surface displacement monitoring. The work program is structured around 2 axes: i) development of robust algorithms; ii) on-line integration (cf. points above).

The methods developed in this Ph.D thesis will be applied to SAR image time-series of the Merapi volcano in Java (cf. Fig. 1). This area was chosen as a specific target for the V0-2 Trial Case on volcanoes by ESA and monitored by Sentinel-1 every 12 days since April 2017. The comparisons between the proposed algorithms and those from the research group at ISTerre will serve as validation.

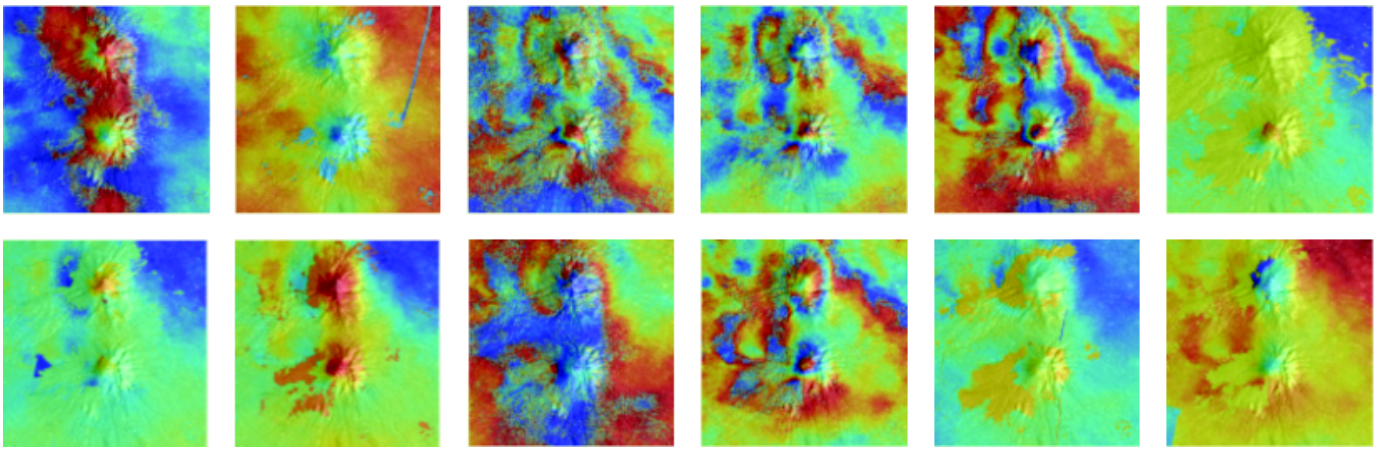

Fig. 1. Image time-series of the Merapi volcano site acquired by Sentinel in 2017.

C. Laboratories and supervision team

The thesis will be held at ONERA, DEMR, Palaiseau, France. Regular visits at Univ. Savoie Mt Blanc, Annecy, will also be planned. the supervision team is the following:

Name	Lab and University	Role	Contact
Guillaume Ginolhac	LISTIC, Univ. Savoie Mt Blanc	Director	guillaume.ginolhac@univ-smb.fr
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D. Candidature

The candidate must have good knowledge and solid skills in mathematics and statistics. Programming skills (python or matlab) are also necessary. Knowledge and experience in SAR imagery will be highly appreciated.

The thesis is fully financed by ONERA, which requires a clearance only attributed to European candidates.

Applicants must send via e-mail to frederic.brigui@onera.fr, guillaume.ginolhac@univ-smb.fr,yajing.yan@univ-smb.fr a CV as well as a transcript of the last year study.

References

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