Title : Neural networks based volcanic model inversion with SAR displacement measurements

Labs : LISTIC, Université Savoie Mont Blanc, ISTerre, Université Grenoble Alpes, LMV, Univesité Clermont Auvergne

Candidate profile : The Ph.D candidate should have good skills in machine learning. Knowledge in inverse problem or geophysics is appreciated.

Ph.D subject description :

Satellite based remote sensing offers a unique source of information to monitor the environnement, with fine spatial resolution, wide coverage and frequent revisit. This enables addressing the challenge of natural hazard monitoring and forecasting, which has a significant societal impact.

The inverse modeling of surface displacement is one of the major techniques of exploring the subsurface feature of volcanœs. The traditional Monte Carlo direct search approaches are computational resources and time consuming, thus cannot respond to operational needs. We will explore the potential of deep learning in volcanic inverse modeling with Interferometry Synthetic Aperture Radar (InSAR) for operational monitoring and forecasting of volcanic hazards. The intrinsic ill-posedness of inversions in volcanology and limited amount of labeled InSAR data make this work challenging.

We tackle the problem of volcanic model inversion, i.e. to estimate model parameters from surface displacement estimations issued from InSAR by solving an inverse problem. This Ph.D thesis will elaborate on our previous proof-of-concept work where a frugal ResNet model was deployed for the first time to estimate the volume change and depth of a spherical volcanic source (i.e. Mogi) from synthetic InSAR displacement fields. This ResNet model exhibits distinct advantages of computational efficiency over the state-of-the-art Monte Carlo direct search methods. For this thesis, the Ph.D student will use more sophisticated volcanic models (e.g. fracture, numerical boundary element models, etc.) allowing for simulations of displacement fields caused by more complex volcanic sources to further increase the generality of the previously proposed ResNet model. One main effort will be devoted to the improvement of the ResNet model prediction accuracy by increasing training data diversity (e.g. divers SAR acquisition geometries, near field/far field and multi-resolution measurements) and by elaborating more adapted loss functions corresponding to appropriate model properties to optimize (e.g. combination of a loss function of estimated model parameters and a loss function of the reconstructed displacement field). These two latter actions also help minimize the ill-posedness. Real InSAR displacement measurements related to both intrusion and reservoir type worldwide volcanœs will be used to fine-tune the ResNet model trained by synthetic data for further validation in real applications.

Selected references :

Lopez-Uroz L., Yan Y., Benoit A., Albino F., Bouygues P., Giffard-Roisin S., Pinel V., Exploring Deep Learning for Volcanic Source Inversion, IEEE Transactions on Geosciences & Remote Sensing, vol.62, doi:10.1109/TGRS.2024.3494253

Dumont, Q., Cayol, V., Froger, J. L., & Peltier, A. (2022). 22 years of satellite imagery reveal a major destabilization structure at Piton de la Fournaise. Nature communications, 13(1), 2649.

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