Internship Offer 2024 / 2025 : Detection and Localization Of Volcanic Fissures in Interferograms Using AI

1. Specifications

Intership level Master's Degree (2nd year) or 3rd year of Engineering School

Start and End Date Depending on availability, 4-5 months. Internship ends with the facility closure in mid-July.

Research Laboratory Laboratoire d'Informatique, Systèmes, Traitement de l'Information et de la Connaissance (LISTIC)

Adress Polytech Annecy-Chambéry, LISTIC, 5 Chemin de Bellevue, 74940 Annecy-le-Vieux, France

https://www.univ-smb.fr/listic

2. Internship Context

*The insa**R** sk**E**leton m**A**pping for **V**olcanic f**I**ssure **D**etection (**REAVED**) project aims to detect and locate volcanic fissures in satellite radar interferograms using artificial intelligence. This approach is based on geometry recognition methods that employ skeleton-based models.*

Satellite radar interferometry, more commonly known as InSAR, provides precise displacement measurements over vast land areas. The availability of satellite constellations and frequent revisit times make it a crucial source of information for monitoring volcanic activity [Biggs, 2014]. Understanding and modeling a volcanic eruption are critical steps in decision-making when dealing with such geological phenomena. The opening of a dyke (volcanic vein) or a fissure (*cfr.* Figure 1), as well as its initial geometry, depends on several factors, including the pressures exerted and the mechanical properties of the ground.

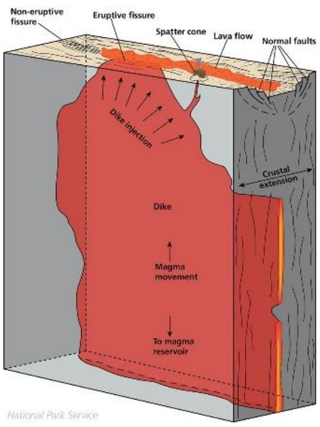

Figure 1: Volcanic Fissure, https://www.nps.gov/articles/000/fissure-volcanoes.htm

J. Biggs, S. K. Ebmeier, W. P. Aspinall, Z. Lu, M. E. Pritchard, R. S. J. Sparks, and T. A. Mather. "Global link between deformation and volcanic eruption quantified by satellite imagery." Nature Communications, 5(1), April 2014.

Volcanic fissures do not have a simple, flat geometry; they narrow and widen, flare, branch, and stratify. Furthermore, their width and shape can also change during an eruption depending on various geological configurations [Cole, 2023]. The identification of volcanic fissures is therefore particularly important for accurate volcanic modeling. However, this task is currently performed manually based on *in-situ* observations [Cayol, 2020]. However, with the continuous increase in the amount of available SAR data, there is a growing need for advanced methods to effectively automate this detection process. Surface deformation detection in interferograms is a well-studied topic in the literature [Mian, 2024], whereas fissure detection has not received the same level of attention. The Piton de la Fournaise on the island of Réunion is the subject of extensive monitoring and has a database spanning 24 years [Dumont, 2022]. Preliminary results obtained by our team on this volcano have demonstrated the feasibility of detecting fissures in the interferograms. Using classical methods, we successfully detected the presence or absence of a fissure within the interferograms from a dozen different satellites [Sermet, 2024]. However, the mere presence or absence of a fissure is far from sufficient for analyzing the geological mechanisms associated with the volcano, and further work is needed to obtain precise locations of these fissures.

R. P. Cole, J. D. L. White, R. J. M. Baxter, M. H. Bowman, T. Dürig, M. Fleming, B. Pooley, J. Ruz-Ginouves, M. T. Gudmundsson, S. J. Cronin, G. S. Leonard, and G. A. Valentine. "A model volcanic fissure with adjustable geometry and wall temperature." Bulletin of Volcanology, 85(3), Springer Science and Business Media LLC, 2023.

V. Cayol, F. Dabaghi, Y. Fukushima, M. Tridon, D. Smittarello, O. Bodart, and J.-L. Froger. "DefVolc: Interface and web service for fast computation of volcano displacement." Copernicus GmbH, 2020.

A. Mian, G. Ginolhac, F. Bouchard, and A. Breloy. "Online change detection in SAR time-series with Kronecker product structured scaled Gaussian models." Signal Processing, Vol. 224, p. 109589, Elsevier BV, 2024.

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

R. Sermet, C. Lin-Kwong-Chon, and Y. Yan. "Automatic Detection of Volcanic Fissures in SAR Interferograms with Machine Learning." MDIS, November 2024.

3. Objectives

The objective of this project is to detect and localize volcanic fissures in satellite radar interferograms using artificial intelligence techniques and skeleton-based geometry recognition. Several types of satellites pass over the Piton de la Fournaise enclosure (*cfr.* Figure 2), allowing for regular and continuous observation. However, each sensor has its own characteristics, including mandated revisit times, operational costs (free or paid), as well as different observation angles and pass directions. One of the initial hypotheses is that the localization of fissures follows a logical pattern depending on the type of InSAR source and the spatial area around the eruptive cone. The second hypothesis explores the similarity between the structure of volcanic fissures and that of skeletons, like action recognition based on skeletal data extracted from photographs. Action recognition from skeletons is a task that involves recognizing human actions from a sequence of point data on joints captured by specific sensors. In our project, the approach is reversed: given the eruptive attributes and the InSAR data, we aim to recognize the fissure and associate it with a geometric shape, regardless of the type of satellite and its field of view.

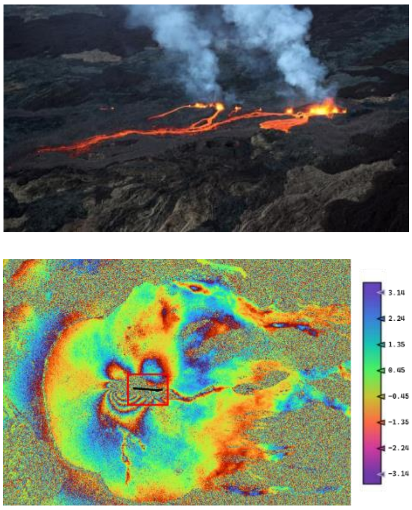

Figure 2: Photo of the Piton de la Fournaise erupting on April 10, 2021, Richard BOUHET / AFP, along with a wrapped InSAR image showing the localized fissure.

The methodology will be based on two actions:

Action 1 We will employ a probabilistic model of the variational autoencoder type to incorporate the attributes of the satellite and the volcanic eruption as a secondary input to the model. This model will be capable of capturing the specific InSAR observation characteristics associated with each sensor by reconstructing the original image while localizing the fissure in the latent space [Parente, 2023].

J. Parente, L. Gonçalo, T. Martins, J. M. Cunha, J. Bicker, and P. Machado, "Using Autoencoders to Generate Skeleton-based Typography." in Artificial Intelligence in Music, Sound, Art and Design - 12th International Conference, EvoMUSART 2023, Held as Part of EvoStar 2023, Brno, Czech Republic, April 12-14, 2023, Proceedings, 2023.

Action 2 We will then adapt human skeleton action recognition methods with an adaptive field of view [Zhang, 2017] to generate variants of volcanic fissures and to accommodate the different radar sensors.

P. Zhang, C. Lan, J. Xing, W. Zeng, J. Xue, and N. Zheng. "View Adaptive Recurrent Neural Networks for High Performance Human Action Recognition from Skeleton Data." 2017 IEEE International Conference on Computer Vision (ICCV), IEEE, 2017

A preliminary schedule is structured as follows: the first month will be dedicated to familiarization with the topic, the data, and the state of the art. The next 2 to 3 months will be focused on developing learning models based on skeleton-like structure recognition applied to volcanic fissures in radar interferograms. Finally, the last months will be dedicated to analyzing the results and showcasing the work.

4. Requirements

The candidate should have knowledge and skills in machine learning and AI programming (Python). Experience in remote sensing and volcanic geophysics would be highly valued, particularly concerning the analysis of InSAR data.

5. Supervisors & Contacts

The main internship supervisor will be Christophe LIN-KWONG-CHON [1] (MCF, LISTIC), with co-supervision from experts in inverse modelling Yajing YAN [2] (MCF HDR, LISTIC) and machine learning Ammar MIAN [3] (MCF, LISTIC). Occasional consultations with application experts will be considered (ISTerre, BRGM, OVPF).

[1] christophe.lin-kwong-chon@univ-smb.fr

[2] yajing.yan@univ-smb.fr

[3] ammar.mian@univ-smb.fr