Postdoctoral Position Proposal:
SAR Time-Series for Detecting Archaeological Ruins Hidden by Jungle

SONDRA, a research alliance between France and Singapore at the Université Paris Saclay in France, focuses on remote sensing of the Earth, specifically utilizing radar systems. The Physics and Modelling team has over 20 years of experience in characterizing radar responses for detection and environmental applications in temperate, boreal, and tropical forests [1] [2] [3] [4].

This postdoctoral position involves research using Synthetic Aperture Radar (SAR) time-series data from the full polarimetric X-band satellite, TeLEOS-2, operated by ST Geoinsights (GI). The primary applications of this research will be in archaeology and monitoring illegal gold mining activities in tropical forests. In addition to research activities, there will be opportunities to teach at CentraleSupélec.

The position is funded for two years, starting on January 1, 2026, at CentraleSupélec, with opportunities for travel to collaborate with GI in Singapore.

Context

We have developed several techniques to analyze both long and short SAR time series in urban and vegetated areas. Geoinsights operates the TeLEOS-2 satellite, which can produce SAR time series that are either locked for three days or unlocked for improved repeatability. Under this project, SONDRA will hire a postdoctoral researcher to further develop techniques for analyzing SAR time series. The researcher will focus on exploring various applications of these SAR time series, beginning with two immediate applications for which SONDRA has already developed analysis tools. They will also collaborate with GI team to integrate the outputs of these techniques into GI's GIS architecture.

Differentiating between Buildings and Vegetation in SAR images:

Building on the work of F. Michenot et al. (2024) [4], we can utilize azimuth diversity in Synthetic Aperture Radar (SAR) to detect Maya temples by analysing a long time series from Sentinel-1. We plan to test the capabilities of Teleos-2, which offers various azimuth angles. This satellite will provide significantly higher resolution imagery and enhance our understanding of the mechanisms involved, thanks to its full polarization capability. In parallel, we anticipate benefiting from ESA BIOMASS SAR images over the same site. Although these full-polarization images have much lower resolution, the P-band data can penetrate deeper, potentially offering additional insights.

We have identified four sites beneath foliage that contain:

- Maya's structures in Ecuador, with some available ground truth [5]
- Khmer sites in Cambodia, with some available ground truth [6]
- Ritigala's temples in Sri Lanka
- Paracou field Station in French Guyana (see image). There are a few "carbets" that are well visible and well located on French IGN maps. The "carbets" are typical small buildings in Guyana, situated within forested areas (see picture).

We propose to begin testing the algorithm developed by Florent Michenot across various sites using Sentinel-1 data. This will allow the postdoc to become more familiar with this tool. Following this step, we will define the areas of interest (AoIs) more accurately.

In the second phase, we will evaluate Teleos-2 data over the specific AoIs identified. Given the higher resolution of Teleos-2, we are unsure of the exact number of SAR images required to apply the algorithm. However, we recommend a minimum of five locked-orbit SAR images, with additional images used to enhance the signal-to-noise ratio. This process will be conducted in at least VV and HH polarizations to further investigate the polarimetric signatures associated with double bounces. The detection results will then be analyzed in relation to the available ground truth, allowing us to assess the advantages of the higher resolution and full polarization offered by Teleos-2.

A second part of the work focuses on illegal gold mining. To address it, we first need to resolve concerns regarding access to ground truth data for illegal gold mining camps that have been destroyed or are about to be destroyed by the French Army.

- We have previously utilized the differences in radar behavior over time by analyzing time series data from ESA's Sentinel-1 satellite. This approach enables us to distinguish environmental stability from non-permanent objects (Taillade et al. (2020), [7]). Additionally, we have recently implemented machine learning and deep learning techniques for target detection by framing these targets as anomalies in the temporal radar signatures of forests (Di Martino et al., (2024), [8]). We propose to test these techniques on known illegal gold mining camps using Teleos-2.
- For older camps, we can only rely on images from Sentinel-1. In this case, we plan to analyze the Sentinel-1 time series data of past illegal gold mining camps to create initial detection maps. If this proves successful, we can expand our observations to identify potential illegal gold mining sites using Sentinel-1 and then utilize Teleos-2 to refine our detection further.

References

[1] L. Thirion, E. Colin and C. Dahon, Capabilities of a forest coherent scattering model applied to radiometry, interferometry, and polarimetry at P- and L-band, *in IEEE Transactions on Geoscience and Remote Sensing*, **44** (2006).

[2] T. Di Martino, B. Le Saux, R. Guinvarc'h, L. Thirion-Lefevre, E. Colin, Detection of Forest Fires through Deep Unsupervised Learning Modeling of Sentinel-1 Time Series. *ISPRS International Journal of Geo-Information*, **12**, (2023).

[3] L. Thirion-Lefevre, E. Colin-Koeniguer, and C. Dahon. Bistatic scattering from forest components. Part I: coherent polarimetric modelling and analysis of simulated results. *Waves in Random and Complex Media*, ***20*** (2010).

[4] Michenot, F., Hinostroza, I., Guinvarc'h, R. and Thirion, L. Identification of Maya ruins covered by jungle using Sentinel-1. Sci Rep 14, 3293 (2024). https://doi.org/10.1038/s41598-024-53068-2

[5] Rostain, Stéphen & Dorison, Antoine & de Saulieu, Geoffroy & Prümers, Heiko & Le Pennec, Jean-Luc & Mejia, Fernando & Freire, Ana & Pagán-Jiménez, Jaime & Descola, Philippe. (2024). Two thousand years of garden urbanism in the Upper Amazon. Science (New York, N.Y.). 383. 183-189. 10.1126/science.adi6317.

[6] Chevance, Jean-Baptiste & Evans, Damian & Hofer, Nina & Sakhoeun, Sakada & Chhean, Ratha. (2019). Mahendraparvata: an early Angkor-period capital defined through airborne laser scanning at Phnom Kulen. Antiquity. 93. 1303-1321. 10.15184/aqy.2019.133.

[7] Taillade, T.; Thirion-Lefevre, L. and Guinvarc'h, R. Detecting Ephemeral Objects in SAR Time-Series Using Frozen Background-Based Change Detection. Remote Sens. 2020, 12, 1720. https://doi.org/10.3390/rs12111720

[8] Di Martino, T., Guinvarc'h, R., Thirion-Lefevre, L. and Colin É., "Convolutional Autoencoder Applied to Short SAR Time Series for Under Canopy Object Detection," IGARSS 2024 - 2024 IEEE International Geoscience and Remote Sensing Symposium, Athens, Greece, 2024, pp. 2785-2788, doi: 10.1109/IGARSS53475.2024.10641180.

Responsibilities:

- Develop/adapt and evaluate methods for detecting archaeological ruins and illegal camps hidden beneath the forest canopy.
- Communicate research findings through peer reviewed publications and conference presentations.
- Foster a positive research group culture and mentor grad/undergrad students.

Required Qualifications:

- Ph.D. in remote sensing, Earth/environmental sciences, engineering, or a related field.
- Expertise in remote sensing of forests.
- Proficiency in computer programming languages (e.g., Python, Matlab, etc.).
- A strong record of independent and productive research, demonsrated by publications in high quality, peer-reviewed journals and conference presentations.
- Excellent oral and written communication skills.

Preferred Qualifications:

- Expertise in SAR time-series processing.
- Experience with machine learning techniques.
- Familiarity with ground truth validation methods.

Position Details:

- **Start Date:** Negotiable but January 1st is preferred.
- **Duration: T**wo years.
- **Annual Stipend:** ~40 k€ (gross amount)
- **Location:** CentraleSupélec (Université Paris-Saclay).

Application Process:

To apply, please submit the following materials:

1. A brief cover letter (1-2 pages) outlining how your background, skills, and career objectives align with the position.
2. Your current CV/resume.
3. Contact information for academic references.
4. One or two sample publications.

Points of contact

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