Deep Learning in Remote Sensing

for Natural Hazard Prevention

PhD Thesis Région Centre Val de Loire / BRGM – Sept 2024

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Scientific Background

In remote sensing, the intensive production of multi-sensor satellite and airborne data of ever-increasing spatial resolution (visible, IR, hyperspectral, lidar, radar, topography, spectral material libraries, etc.) enables very detailed observation of the earth. In particular, ENMAP satellite has opened up to the scientific community a considerable field of investigation for earth observation with a spatial resolution of 30m. This potential remains under-utilized, however, as conventional methods are unable to absorb such a mass of data, especially hyperspectral imagery, which extends over hundreds of bands.

Artificial intelligence techniques, which have revolutionized the field of Computer Vision, are opening up a new avenue in remote sensing for semantic segmentation, with the automatic extraction of characteristics of features exposed to natural hazards. With climate change, natural disasters are on the increase, demonstrating the urgent need to establish up-to-date risk scenarios.

The aim of this thesis is to evaluate the contribution of artificial intelligence to better assess vulnerability in the face of natural hazards, by unfolding impact scenarios from a multi-risk, multi-scale perspective.

The highly multimodal and heterogeneous nature of the data collected by remote sensing to characterize a territory has given rise to a new methodological challenge: developing suitable network architectures for the classification and semantic segmentation of this massive and complex data. What's more, the lack of remote sensing training databases is driving work towards semi-supervised approaches with partially annotated data. It is through the pooling of heterogeneous data proposed in this thesis that ground truth will be substantially enriched. Network models will also have to adapt to degraded situations abroad, where some data are unavailable.

This work is closely linked to the Région Centre Val de Loire CERES project - *Mapping and characterizing exposed elements in the CVL region from satellite images* - with application prospects for the region's economic operators, concerned by the growing

risks associated with flooding and building cracking. CERES is in charge of access to paid data and intensive online computing on the deep learning models developed during the thesis. This work is also in synergy with actions carried out at BRGM (H2020 COCLICO, VIGIRISKS, ANR RESIFLEX) and the ANR-IA, where joint work is underway between PRISME and BRGM.

Work Schedule

The first year of the thesis will begin with a state-of-the-art review of deep learning algorithms applied to remote sensing. This will be followed by an inventory of exploitable data sources, the implementation of a data collection and processing platform, and experimentation with the extraction of a few relevant features from deep learning models derived from the state of the art in semantic segmentation. For the characterization of exposed elements, the aim is to identify the spatial, geometric, spectral and documentary characteristics of interest, which can be exploited in the various data sources and are relevant to the prevention of natural hazards.

We already have a database of images acquired in the Loiret region during the AGEOTHYP program, covering a wide range of terrain (crops, forests, urban areas, rivers, etc.), as well as satellite and documentary data on study sites abroad. The PhD student will have to familiarize himself/herself with the risk theme by consulting BRGM risk experts in order to list the criteria to be analyzed in order to build up a multi-risk issues database. The proximity of the study site will facilitate on-site surveys to enrich the ground truth. The cost of access to certain satellite data sources will be covered by the CERES regional project.

For data processing, the aim is to evaluate the performance of various online or local computing solutions, and to experiment with a few advanced state-of-the-art deep learning models for extracting the characteristics of elements exposed to climatic hazards. The power of the CaSciModot supercomputing infrastructure integrated into the DataCentre Régional Centre Val de Loire on the Grand Campus Orléans, including BRGM and the university, will be used to run the deep learning algorithms. The Region CERES project will also enable the models to be tested using pay-per-use online computing solutions.

During the second year, a ground truth database will be set up to train the algorithms. Network architectures adapted to heterogeneous modalities will be proposed. The possibility of multi-scale processing (building or urban aggregation) will be studied. Experimental validation will be carried out in the Loiret pilot area, where a large number of image modalities with good spatial resolution are available. Other experiments may be carried out on foreign sites, where the absence or scarcity of certain data will lead to a degraded mode.

The third year will be devoted to applying the results of semantic segmentation to one or more risk scenarios (floods, earthquakes, landslides, etc.), and to finalizing the analysis and evaluation of the contribution of deep learning methods to the mapping of issues. The CERES project's economic partners will enhance the applicative vocation of the work, with a focus on the Blois conurbation and taking into account the concerns of the insurance sector.

The work will be promoted through participation in national and international conferences on general or specialized image processing (artificial intelligence approaches, remote

sensing, etc.) and the publication of a journal article.

PRISME - BRGM Collaboration

Computer Vision - AI at PRISME

He has acquired expertise in Deep Learning image processing and hyperspectral imaging:

Deep learning approaches have been used for the semantic segmentation of images, with spectacular results compared with conventional methods, first in the medical field and then in public image databases (e.g. CityScapes: urban scenes or common objects: SBD). Parallel work in this area has also been applied to precision agriculture, animal video surveillance (sheepfolds, zoos, etc.) and heritage (monuments, paintings, etc.).

The hyperspectral imaging modality, which is highly discriminating but generates huge volumes of data, was first tested in the medical field (visualization of tissue spectra in the operating room), then in remote sensing (image segmentation using active contours on a graph), in particular with aerial images acquired by BRGM Orléans during the AGEOTHYP program (detection of clay soils at risk).

Risks and Prevention Division - BRGM

The team makes available heterogeneous data acquired in the field or collected in its databases, and has the expertise to exploit them in multi-risk scenarios:

BRGM has a hyperspectral dataset. The images are centered on a study area west of Orléans covering some 300 km², i.e. 170 images of 408 spectral bands (400 - 2500 nm) with a spatial resolution of 1 to 2 m. A geospatial database is also available to serve as ground truth (laboratory and in situ spectral libraries, spatialized geotechnical data and mineralogical analyses). Another foreign study site will be selected to work in degraded mode. Other Open Source data will be collected on the Loiret study site, depending on availability and quality: thermal infrared emissivity, LIDAR topography, SAR subsurface, IGN database.

BRGM's risk specialists have the expertise to assess the vulnerability to natural hazards. As part of the RISQNAT research program "Building impact scenarios for the prevention of natural hazards", they are looking into cost-effective solutions for the production of spatialized information over vast study areas, and the development of platforms integrating predictive models from a multi-risk, multi-scale perspective.

Funding

Region Centre - Val de Loire thesis grant (36 months) co-financed with BRGM Orléans.

The Region CERES project launched in oct. 2023 also provides a substantial budget for experimentation, with access to paid-for satellite data and online computing.

Profile required

Candidates with a research Master's degree in computer science should have extensive knowledge of image processing, including deep learning techniques and their implementation in software and hardware. Fundamental notions of remote sensing are also welcome. Fluency in English is essential. Autonomy, scientific rigor and great motivation for the proposed subject will be undeniable assets for the successful completion of the thesis.

Candidates must submit the following documents in a single pdf file: CV + cover letter + Master's grades - optional letters of recommendation.

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