PhD Position : Semantic Segmentation of Heterogeneous Data by Deep Learning for the Prevention of Natural Hazards

The aim of this thesis is to evaluate the contribution of artificial intelligence to better assess the vulnerability of assets facing natural hazards, by unfolding impact scenarios in a multi-risk and multi-scale perspective. The highly multimodal and heterogeneous character of remote sensing data (visible, IR, hyperspectral, lidar, radar, topography, spectral libraries of materials ....) to characterize a territory, brings out a new methodological challenge: to develop network architectures adapted for the classification and semantic segmentation of these massive and complex data.
This thesis work is also in synergy with the actions carried out at BRGM (H2020 COCLICO, VIGIRISKS, ANR RICOCHET projects) and the ANR-IA where joint work has been initiated between PRISME and BRGM.

Semantic Segmentation of Heterogeneous Data
by Deep Learning for the Prevention
of Natural Hazards

PhD Position granted by Centre Val de Loire Region and BRGM - Oct 2022

University of Orléans - PRISME Laboratory – Image & Vision Team
Yves Lucas – Associate Professor HdR

BRGM Orléans - Risks and Prevention Department
Audrey Hohmann - Natural hazards engineer, GIS and remote sensing
Caterina Negulescu - Earthquake Risk Engineer

Scientific background
In the field of remote sensing, the production of multi-sensor satellite and airborne data (visible, IR, hyperspectral, lidar, radar, topography, spectral libraries of materials ...) which is experiencing a spectacular explosion allows a very fine observation of the earth but this potential remains underutilized to establish risk scenarios [1] because conventional methods cannot analyze such a large amount of data, especially those from hyperspectral imagery that are spread over hundreds of bands.
Artificial intelligence techniques open a new way for the automatic processing of heterogeneous remote sensing data [2-9] including hyperspectral images [10-12] by producing semantic segmentation maps. On the other hand, the commissioning of the ENMAP hyperspectral satellite will open to the scientific community a considerable field of investigation for terrestrial observation with a spatial resolution of 30 m.

The aim of this thesis is to evaluate the contribution of artificial intelligence to better assess the vulnerability of assets facing natural hazards, by unfolding impact scenarios in a multi-risk and multi-scale perspective. The highly multimodal and heterogeneous character of remote sensing data (visible, IR, hyperspectral, lidar, radar, topography, spectral libraries of materials ....) to characterize a territory, brings out a new methodological challenge: to develop network architectures adapted for the classification and semantic segmentation of these massive and complex data.

The implementation of deep learning on hyperspectral images in remote sensing must face the lack of training datasets. Already, the addition of texture information, coverage index (NVDI) or surface model (NDSM) could improve the extraction of geographical features. Similarly, reducing the number of network parameters, transfer learning techniques and data

augmentation were able to compensate for the small dataset size that could lead to overlearning. Optimized loss functions have also been proposed because the shots are directional in remote sensing.
But it is through the mutualisation of heterogeneous data proposed in this thesis, that the ground truth will be substantially enriched. By integrating directly into the architecture of a deep neural network the fusion of different sources of heterogeneous data, it is then possible to carry out this complex integration to improve the accuracy of the mapping of the assets and to evaluate it at different scales. Similarly, training on partially annotated or semi-supervised data could meet the desired extension of network models to degraded situations, as also envisaged in this thesis, by experimenting on a complementary site abroad after a study on the Loiret site, where many modalities of images and geographical data are available with all the desired spatial resolution.

Work program

The first year of the thesis will start with a state of the art on deep learning algorithms applied to remote sensing and in particular to hyperspectral images. The next step will be to set up a semantic segmentation using the main imaging modality: hyperspectral imagery. For this, we already have the image base acquired in the Loiret during the AGEOTHYP program and which includes various terrains (crops, forests, urban areas, rivers, etc ...). The doctoral student will have to appropriate the risk theme by going to consult the BRGM risk experts in order to list the criteria to be analyzed to constitute a multi-risk stakes database. A preliminary denoising of hyperspectral images by neural network could be implemented according to the state of the art. The proximity of the study site will facilitate on-site surveys to enrich the ground truth. The power of the CaSciModOT computing mesocenter accessible by BRGM and PRISME will be used to run the deep learning algorithms.
During the second year, a ground truth database will be built to train the algorithms. Network architectures adapted to the fusion of heterogeneous modalities will be proposed. The possibility of multi-scale processing (buildings or urban aggregation) will be studied. The experimental validation will be done on the pilot area of the Loiret where we have many image modalities and with a good spatial resolution. Other experiments may be considered on remote sites (Africa) where the absence or scarcity of certain data will lead to a degraded mode.
The third year will be devoted to the application of the results of the semantic segmentation on one or more risk scenarios (floods, earthquakes, landslides ...), as well as to the finalization of the analysis and evaluation of the contributions of deep learning methods for the mapping of assets.
The work will be valorised by the participation in national and international conferences of general or specialized image processing (artificial intelligence approaches, remote sensing…) and the publication of a journal article.

Thesis Environment : PRISME – BRGM Collaboration

It started in 2015 with a common supervision of a Master 2 internship financed by an RTR Image grant. It continued with the signing of a collaboration agreement signed in 2017 between BRGM and PRISME during the theses of K.Tabia [13-14] and E. Ducasse [15] around hyperspectral imaging for mapping swelling clays from soil reflectance measurements. The PRISME- BRGM collaboration brings since 2015 the necessary complementarity to such a challenge:

Image & Vision Team - PRISME
It has acquired expertise in the field of hyperspectral imaging and in image processing by Deep Learning:
- hyperspectral imaging, an emerging imaging modality remarkable for its extreme discriminating power, was first experimented in the medical field (visualization of tissue spectra in operating rooms) [16-17] and then in remote sensing (image segmentation by active

contours on a graph) [13-14] with, in particular, aerial images acquired by BRGM Orléans during the AGEOTHYP program (detection of at-risk clayey soils)

- Deep learning approaches have been used for the semantic segmentation of images with spectacular results compared to classical methods. Our first works concerned the medical domain where state of the art convolutional neural networks were evaluated [18-21] then new architectures were proposed with an original learning strategy whose generic scope has been successfully validated on public image bases that are references (e.g. CityScapes: urban scenes or common objects: SBD) [22-23]. Within Image & Vision Team, parallel works have also been applied to precision agriculture [24-25].

Risks and Prevention Department – BRGM
The Department makes available heterogeneous data acquired in the field or collected in its databases and has the expertise to exploit them by developing multi-risk scenarios: BRGM's risk specialists have the expertise to assess the vulnerability of the assets to natural hazards. Within the RISQNAT research program "building impact scenarios for natural hazard prevention", they are interested in solutions for producing spatialized information over large study areas at a lower cost and in the development of platforms integrating predictive models from a multi-risk and multi-scale perspective [27].

This thesis work is also in synergy with the actions carried out at BRGM (H2020 COCLICO, ANR RICOCHET projects and VIGIRISKS Platform (https://www.brgm.fr/fr/site-web/vigirisks-plateforme-scientifique-services-risques-naturels)) and the ANR-IA where joint work has been initiated between PRISME and BRGM.

Funding
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Candidate profile
The candidate with a Master's degree in computer science should have a broad knowledge of image processing, including deep learning techniques and their implementation in software and hardware. Fundamental notions in remote sensing are also required. Fluency in English is essential. Autonomy, scientific rigor and a strong motivation for the proposed subject will be undeniable assets to successfully complete the thesis.

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

Contacts

yves.lucas@univ-orleans.fr
a.hohmann@brgm.fr
c.negulescu@brgm.fr

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