Spatial Data Sciences Seminar

6th June 2024

ABSTRACTS

- **Large Language Models for Captioning and Retrieving Remote Sensing Images**. João Daniel Silva (IST), João Magalhães (IST), Devis Tuia (IST), Bruno Martins (IST).

Image captioning and cross-modal retrieval are examples of tasks that involve the joint analysis of visual and linguistic information. In connection to remote sensing imagery, these tasks can help non-expert users in extracting relevant Earth observation information for a variety of applications. Still, despite some previous efforts, the development and application of vision and language models to the remote sensing domain have been hindered by the relatively small size of the available datasets and models used in previous studies. In this work, we propose RS-CapRet, a Vision and Language method for remote sensing tasks, in particular image captioning and text-image retrieval. We specifically propose to use a highly capable large decoder language model together with image encoders adapted to remote sensing imagery through contrastive language-image pre-training. To bridge together the image encoder and language decoder, we propose training simple linear layers with examples from combining different remote sensing image captioning datasets, keeping the other parameters frozen. RS-CapRet can then generate descriptions for remote sensing images and retrieve images from textual descriptions, achieving SOTA or competitive performance with existing methods. Qualitative results illustrate that RS-CapRet can effectively leverage the pre-trained large language model to describe remote sensing images, retrieve them based on different types of queries, and also show the ability to process interleaved sequences of images and text in a dialogue manner.

- **An empirical linear mixed-effects model approach to compare TROPOMI/Sentinel 5 Precursor NO2 observations with ground-based measurement in the Iberian Peninsula.** Rita Cunha (CoLab +ATLANTIC), Ana Oliveira (CoLab +ATLANTIC), Inês Girão (CoLab +ATLANTIC).

Air quality is an essential aspect in Urban areas, as atmospheric pollution is increasingly perceived to be responsible for substantial degradation of the quality of life, worldwide. In this study, spatial pattern, seasonality, and the relation between local and remotely sensed observations of nitrogen dioxide (NO2) is analyzed, in Lisbon, Porto, Barcelona, and Madrid . Two time series of NO2 concentration levels are retrieved from publicly available databases: (i) tropospheric column nitrogen dioxide (NO2CT) level-2 product imagery (OFFL; 3.5x7km), from Copernicus's Sentinel-5 Precursor mission, (European Space Agency (ESA) 2020; European Space Agency 2020); and (ii) officially reported in-situ NO2 concentrations from the European Environment Agency (EEA 2020).

The daily/weekly statistical summaries of NO2CT and NO2 concentrations over the territory of the Iberian Peninsula were calculated to match the temporal granularity between the two raw datasets, considering the period from January 2020 to December 2020. The aim is to recognize the capability of NO2CT to assess: (i) what is the relation between NO2CT and in-situ NO2 concentrations, in each and across the cities and (ii) what is the seasonal cycle of NO2 concentrations in the case study city.

Processing and quality assessment (QA) of the satellite data followed the procedures per Apituley et al. (2018), including re-gridding the Level-2 data into regular grids (Level-3) at a 2.5x2.5 km pixel resolution (pproximate to the satellite's native resolution, at nadir), and excluding pixels where QA<0.75 (i.e., those with high probability of cloud contamination). In addition, images with a significative number of unqualified pixels, over each city center, were excluded from the analysis – this was done by visual inspection of individual images. Weekly averages were calculated from

qualified pixels and images, excluding week-end days. To assess the relation between satellite and in-situ data, a linear mixed-effects regression through the origin method was adopted, controlling for the variance and autocorrelation, per each site.

Preliminary results show a significant agreement between both satellite and in-situ weekly NO2 concentration levels, with a mean correlation coefficient (R2) of 0.80 significant at the 99% confidence level. According to model results each unit of µmol/m2 NO2CT equals 0.3 µgr/m3 of in-situ NO2. Seasonally, higher concentrations of both tropospheric and in-situ NO2 were found in the winter weeks of the year (January to February 2020); conversely, lower values are registered during the summer, as expected due to the inverse relation between air temperature and NO2 concentration levels. Spatially, the NO2CT plumes reveal the footprint of each metropolitan area, particularly the stark accumulation of NO2CT where road traffic converges, and/or terrain altitude is lower. While the satellite NO2CT levels have the advantage of disclosing the regional spatial patterns, there are data limitations due to cloud cover, especially during the winter. In periods of consecutive days with significative cloud cover, weekly average NO2CT values become less representative of the corresponding week, hence, with lower agreement with in-situ data. Nonetheless, geospatial intelligence methods (such as machine learning and artificial intelligence), together with candidate explanatory variables such as road-traffic intensity, weather conditions, and geochemical atmospheric models, provide potential pathways to fill in these gaps, and improve the original satellite's spatial resolution. Next steps of this work will explore such data driven methodologies to develop a satellite-based NO2 downscaling model, aiming to improve the Sentinel's 5P level of detail, and ensure temporal continuity.

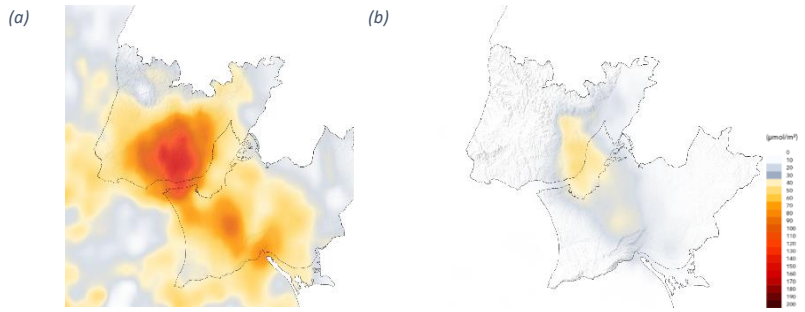

Figure 1 – Tropospheric NO_2 observed of Lisbon Metropolitan Area, based on weekdays average on (a) first week of January 2020 and (b) first week of July 2020.

- Space-time characterization of fire-related air pollutants over Portugal - Rita Durão (IPMA), Célia Gouveia (IPMA), Madalena Simões(IPMA), André Brito(IPMA) e Ana Russo (FCUL).

- Exploring the uncertainty of landslide susceptibility via a Probabilistic Neural Network. Helga Jordão (IST), Amilcar Soares (IST).

- A Predictive Model of Drought Severity. A Case Study of Southern of Portugal. A. Miguel Gomes (IST), Cristina Meira (ISEP), A. Soares (IST).

- Uncertainty Assessment by using a Multi-Solution approach in inverse problems. J.L. Alves (UFRGS), J.F. Costa (UFRGS), Amilcar Soares (IST).

In some applications of Earth Sciences in difficult to access sites - remote or underground - the scarcity of information is sometimes so great that the prediction of the average behavior of a physical phenomenon becomes meaningless, making the prediction of uncertainty the main target of characterizing the phenomenon. In these situations it is usual to resort to all types of information that are directly or indirectly correlated with the physical phenomenon that are treated by inverse methods. Geophysical inversion methods aim to generate models of the properties of interest that give rise to the real geophysical image.

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In this study, a new approach is presented based on the Niching Genetic Algorithms method, to allow a diverse set of optimal solutions in a multi-modal space, thus overcoming the major limitation of seismic inversion methods, which is access to the uncertainty of the final models. In the new seismic inversion approach proposed in this study, in each iteration of the optimization process, niches of petrophysical properties models are calculated with a Machine Learning Clustering method based on a distance measure of the similarity between synthetic seismic models in a Multidimensional scaling (MDS) space. For the set of niches, the evolutionary process (Niching Genetic Algorithm) will produce different solutions, but close to the observable data, the real seismic, giving rise to a multi-solution seismic inversion methodology. The new method is illustrated in a case study with the objective of risk assessment at early stages of exploration of a complex geological target.