COLLABORATIVE DOCTORAL PARTNERSHIPS – CALL 2020

THEMATIC FIELD 6: Artificial Intelligence for earth observation

JRC RESEARCH AREA DESCRIPTION

Methods for analysis of satellite time series and detection of changes in human settlements

The most pervasive form of land-cover change around the world and in developing countries in particular is human settlement expansion. In many cases, new human settlements as well as existing settlements expand informally and these expansions occur in areas that were previously covered by natural vegetation. Rapid urbanization and changes in the landscape put pressure on adequate and effective urban planning. The growth of cities also results in degradation of natural habitats, changes in species composition, cities' micro-climate, energy flows and subsequently creating urban heat islands. There is an urgent need for effective and sustainable urban planning and development management, supported by adequate and up-to-date geospatial information. Satellite time series data have proven to be an effective data source for change detection [1]–[4] and in particular, time series analyses of hyper-temporal satellite data has been successfully applied for land cover change detection. Timely information on urban expansion provided by satellite imagery can be vital in ensuring integrated spatial planning and land use management. Despite the availability of long satellite time series and the high temporal density of observations provided by Copernicus Sentinel data, it is still very challenging to process such large volumes of dense time series in a systematic way and to derive systematically near real-time information on changes in the landscape. Novel methods based on Artificial Intelligence (AI) are expected to convert satellite image time series into valuable earth Observation products with impact in new applications for understanding of the Earth cover spatio-temporal processes over long periods of time. Building on in-house developed machine learning tools for automatic information extraction from satellite imagery (e.g. the Symbolic Machine Learning (SML) [5]), this study proposes to develop new AI methods for time-series-based analysis which aims at detecting changes in human settlements from satellite data (as the core input data) in conjunction with other socio-economic and field environmental datasets.

The developed methodology should enable the balancing between runtime and accuracy with the recent availability of multiple time points per pixel, created by periodically performed satellite scans delivered by the Sentinel 1 and 2 constellations. It should allow also identifying efficiently both abrupt and gradual changes at multiple timescales from multivariate data including satellite, socio-economic and environmental data. Both types of changes can indicate that important events have occurred and influence the decisions on policy priorities and actions: e.g. sudden onset disaster that result in damages to physical assets or progressive changes due to gradual expansion of a city. To address these challenges and generate accurate, cost-effective, change detection maps of human settlements, the proposed research will use spectral information from Sentinel data stacks (available through the Copernicus Data and Information Access Services (DIAS)) while exploiting a machine-learning model based on SML and Deep Neural Network (DNN). The developments and implementations will benefit from high-performance computing for intelligent and scalable computation of classification processes offered by the JRC Big Data Infrastructure (JEODPP) [6] . The methodology should be generic enough to allow the detection of changes in any land cover time, for continuous monitoring of human settlements and for the provision of consistent time series of human settlements information.

The study capitalize on the last developments in the framework of the Global Human Settlement Layer project (GHSL) which aims at delivering global dynamic information on human settlements in terms of built-up areas, population and settlements classification using in house developed machine learning methods.

It will directly contribute to the priorities of the new Commission (Green Deal, Europe fit for the digital age, an economy that works for people, a stronger Europe in the world). The proposed topic is an essential contribution to the new project portfolio on Human Centric AI applied to Earth Observation for public policies.

Scenario prediction and modelling of Human Settlements growth

Human settlements are at the centre of the earth system. The growth of their population and the related global urbanization pose one of the major challenges to a sustainable future. Hence, it is essential to understand drivers, dynamics, and impacts of the human settlements development. Besides, there is a continued need for globally comparable and standardized urban environment datasets and projections, particularly as internationally coordinated and global efforts for sustainable development, addressing climate change, and health related interventions and initiatives are undertaken, such as under the Sustainable

Development Goals [1]. With the availability of High Resolution imagery from the European Copernicus Earth Observation Program supported by the development of a highly capable European cloud-computing infrastructure (e.g. DIAS, EuroHPC) and Artificial Intelligence tools and methods, there is an opportunity to develop state-of-the art modelling capacity for scenario prediction and modelling of Human Settlements growth.

The study proposes the development of a framework for understanding the dynamics of human settlements growth and forecasting the growth in built-up areas and their population building on satellite time series, in combination with environmental and socio-economic data. It will exploit the unprecedented amount of finer spatial scale data on aspects of the Earth's environment from remote-sensing, demographic, social, and economic sources. The framework should leverage on state-of-the-art technology of machine learning of remote-sensing data and spatially explicit modelling of human settlements growth driven by policy needs: i.e. understating land conversion and land use changes, urban management planning, adaptation to climate change, exposure and vulnerability to natural disasters and urban resilience. It will capitalize on the last developments in the framework of the Global Human Settlement Layer project (GHSL) which aims at delivering global dynamic information on human settlements in terms of built-up areas, population and settlements classification [1] using in house developed machine learning methods [2].

Among the different expected outputs of the high precision and high-resolution modelling/forecasting framework are global spatial grids of projected settlements growth for the periods 2030 and 2050 at a spatial resolution of 1 km. For specific applications related to risk assessment (such as risks related to sudden onset disasters), finer scale population data (at 100 meters) for different points in time (day/night, monthly) will be created for defined regions of the world comprising rural and urban areas [4]. The study will explore the synergies between cloud, extreme scale data, high performance computing (EuroHPC Joint Undertaking) infrastructure and machine-learning methodologies underpinning the JRC Big Data Infrastructure (JEODPP) [5] and the Copernicus Data and Information Access Services (DIAS) as well as the future Planet Earth initiative supported by DG CNECT. It will directly contribute to the priorities of the new Commission (Green Deal, Europe fit for the digital age, an economy that works for people, a stronger Europe in the world).

The proposed topic is an essential contribution to the new project portfolio on Human Centric AI applied to Earth Observation for public policies. It will provide essential information on continuous urbanization and human settlements projection scenarios that are necessary to gauge future demands for infrastructure and for improving sustainability, resilience and inclusiveness of urban and rural areas

MAIN POLICY FIELDS

The proposed research is relevant for several of the new Commission activities including Europe fit for the digital age, a European Green Deal, and a stronger Europe in the world since the outcome will support the monitoring of the SDG's, the Sendai Framework for DRR 3, the New Urban Agenda. The AI related work will feed into initiatives such as the European Open Science Cloud (EOSC), the European Data Infrastructure (EDI), the European High Performance Computing Joint Undertaking (EuroHPC Joint Undertaking).

LINKS / URL WEBSITES

Global Human Settlement Layer of the JRC:

- https://ghsl.jrc.ec.europa.eu/

JRC Earth Observation Data and Processing Platform (JEODPP)

- https://jeodpp.jrc.ec.europa.eu/home/

Copernicus Earth Observation Program

- https://scihub.copernicus.eu/dhus/

Copernicus DIAS

- https://www.copernicus.eu/en/access-data/dias

Implications of population and urban growth on Sustainable Development:

- https://news.un.org/en/story/2019/04/1035841

LINKS / REFERENCES TO PUBLICATIONS

Methods for analysis of satellite time series and detection of changes in human settlements

[1] K. M. de Beurs and G. M. Henebry, "A statistical framework for the analysis of long image time series," *Int. J. Remote Sens.*, vol. 26, no. 8, pp. 1551–1573, Apr. 2005, doi: 10.1080/01431160512331326657.

[2] J. Verbesselt, R. Hyndman, G. Newnham, and D. Culvenor, "Detecting trend and seasonal changes in satellite image time series," *Remote Sens. Environ.*, vol. 114, no. 1, pp. 106–115, Jan. 2010, doi: 10.1016/j.rse.2009.08.014.

[3] R. S. Lunetta, J. F. Knight, J. Ediriwickrema, J. G. Lyon, and L. D. Worthy, "Land-cover change detection using multi-temporal MODIS NDVI data," *Remote Sens. Environ.*, vol. 105, no. 2, pp. 142–154, Nov. 2006, doi: 10.1016/j.rse.2006.06.018.

[4] R. E. Kennedy, W. B. Cohen, and T. A. Schroeder, "Trajectory-based change detection for automated characterization of forest disturbance dynamics," *Remote Sens. Environ.*, vol. 110, no. 3, pp. 370–386, Oct. 2007, doi: 10.1016/j.rse.2007.03.010.

[5] M. Pesaresi, V. Syrris, and A. Julea, "A New Method for Earth Observation Data Analytics Based on Symbolic Machine Learning," *Remote Sens.*, vol. 8, no. 5, p. 399, May 2016, doi: 10.3390/rs8050399.

[6] P. Soille *et al.*, "A versatile data-intensive computing platform for information retrieval from big geospatial data," *Future Gener. Comput. Syst.*, vol. 81, pp. 30–40, 2018, doi: https://doi.org/10.1016/j.future.2017.11.007.

Scenario prediction and modelling of Human Settlements growth

[1] Y. Zhou, A. C. G. Varquez, and M. Kanda, "High-resolution global urban growth projection based on multiple applications of the SLEUTH urban growth model," *Sci. Data*, vol. 6, no. 1, Dec. 2019, doi: 10.1038/s41597-019-0048-z.

[2] C. Corbane *et al.*, "Big earth data analytics on Sentinel-1 and Landsat imagery in support to global human settlements mapping," *Big Earth Data*, vol. 1, no. 1–2, pp. 118–144, 2017, doi: 10.1080/20964471.2017.1397899.

[3] M. Pesaresi, V. Syrris, and A. Julea, "A New Remote Sensing Data Classification Method Based on Symbolic Machine Learning," http://dx.doi.org/10.2788/638672, 2015.

[4] S. Freire, A. Floczyk, and S. Ferri, "Modeling Day- and Nighttime Population Exposure at High Resolution: Application to Volcanic Risk Assessment in Campi Flegrei," presented at the

12th International Conference on Information Systems for Crisis Response and Management, 2015.

[5] P. Soille *et al.*, “A versatile data-intensive computing platform for information retrieval from big geospatial data,” *Future Gener. Comput. Syst.*, vol. 81, pp. 30–40, 2018, doi: https://doi.org/10.1016/j.future.2017.11.007.