1. PHD PROJECT DESCRIPTION

Project title:

Integration of GeoAI methods, GIS, and remote sensing data in the modelling of dynamic land cover changes in urbanised areas

1.1. Project goals

The project aims to develop integrated methods using geospatial AI (GeoAI), geographic information systems (GIS), and remote sensing (RS) data for modelling, classification, and prediction of changes in urban space consistent with sustainable development principles. An additional objective is to create and test prototype models based on deep neural networks (DL), which will enable efficient processing of spatial data and forecasting of changes in selected components of the urbanised environment (e.g., changes in development types, disappearance of green areas, transformation of water relations). An element of the project is also the effective integration of thematic GIS data (road networks, administrative boundaries, master plans) with GeoAI models, allowing local spatial context to be considered. The project will result in a reproducible analytical workflow to assess urbanisation dynamics, identify patterns of spatial change, and support planning decisions.

1.2. Outline

The project is concerned with integrating GeoAI methods, GIS, and remote sensing data in modelling dynamic land cover changes in urbanised areas. The aim is to develop modern, scalable, automated analysis methods based on machine learning with spatial context. High-resolution satellite and aerial data, open GIS data, and artificial intelligence will be used. The integration will enable the detection of complex patterns of change and their linkage to land use data. The project assumes that solutions will be open, using open-source tools and making results available in public repositories. The case studies will cover selected cities in Poland, but the methodology will be universal. The interdisciplinary and international project supports the Sustainable Development Goals, particularly Goal 11: *Make cities inclusive, safe, resilient and sustainable* (SDG 11).

1.3. Work plan

Main project milestones:

- review of scientific literature in the area of GeoAI, GIS, and analysis of dynamic changes in urban land cover,
- analysis of existing methods for detection and prediction of land cover changes (especially in urban areas),
- acquisition and pre-processing of high-resolution remote sensing data and open selected vector databases,
- analysis of available GeoAI methods for their usefulness in detecting and monitoring land cover changes,
- testing of simple GeoAI classification models on selected test areas,
- development and optimisation of a GeoAI model aimed at the analysis of dynamic land cover changes in urbanised environments,
- evaluation of the quality and interpretability of the model results on test data from different periods, under urban conditions,

- development of a predictive model taking into account urban trends and factors limiting or stimulating urban development,
- uncertainty analysis of the predictive models - assessing which land cover types and urban areas are predicted with the highest degree of certainty and which need further refinement,
- preparation of an analytical tool (software plug-in/script, code repository) for automatic detection and forecasting of land cover changes in urban areas,
- preparation of technical and scientific documentation of the project results.

1.4. Literature *(max. 7 listed, as a suggestion for a PhD candidate's preliminary study)*

- Janowicz K., Gao S., McKenzie G., Hu Y., Bhaduri B., 2019. GeoAI: spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond. *International Journal of Geographical Information Science* 34(4): 625–636. DOI 10.1080/13658816.2019.1684500.
- Li W., 2020. GeoAI: Where machine learning and big data converge in GIScience. *Journal of Spatial Information Science* 20: 71–77. DOI 10.5311/JOSIS.2020.20.658.
- Liu P., Biljecki F., 2022. A review of spatially-explicit GeoAI applications in urban geography. *International Journal of Applied Earth Observation and Geoinformation* 112: 102936. DOI 10.1016/j.jag.2022.102936.
- LeCun Y., Bengio Y., Hinton G., 2015. *Deep learning*. Nature 521(7553): 436–444. DOI 10.1038/nature14539.
- He H., et al., 2024. Time-series land cover change detection using deep learning-based temporal semantic segmentation. *Remote Sensing of Environment* 305: 114101. DOI 10.1016/j.rse.2024.114101.
- Li W., et al., 2025. Automatic identification of potential renewal areas using remote sensing data and GeoAI. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 18: 8523–8535. DOI 10.1109/JSTARS.2025.3549618.
- Hanny D., Resch B., 2025. Multimodal GeoAI: An integrated spatio-temporal topic-sentiment model for the analysis of geo-social media posts for disaster management. *International Journal of Applied Earth Observation and Geoinformation* 139: 104540. DOI 10.1016/j.jag.2025.104540.

1.5. Required initial knowledge and skills of the PhD candidate

- practical skills in remote sensing data processing,
- practical knowledge of using GIS software (ArcView, QGIS, and others),
- programming skills,
- basic experience in data processing modelling,
- basic knowledge of machine learning methods (GeoAI),
- analytical thinking ability,
- independence and creativity in solving scientific problems,
- research passion and enthusiasm,
- distance to reality,
- teamwork skills are not required.

1.6. Expected development of the PhD candidate's knowledge and skills

The candidate for the Doctoral School should develop skills in effectively using spatial and remote sensing data analysis tools and in automating the implemented processes. The PhD candidate is assumed to develop competencies in GeoAI and machine learning and acquire advanced skills in developing GIS software plug-ins and scripts. The PhD student should also develop skills in using GIS in urban research. The envisaged development should prepare to conduct independent scientific research at the interface of geography, spatial management, and geoinformation, as well as develop skills in communicating the results of scientific work and practical activities.