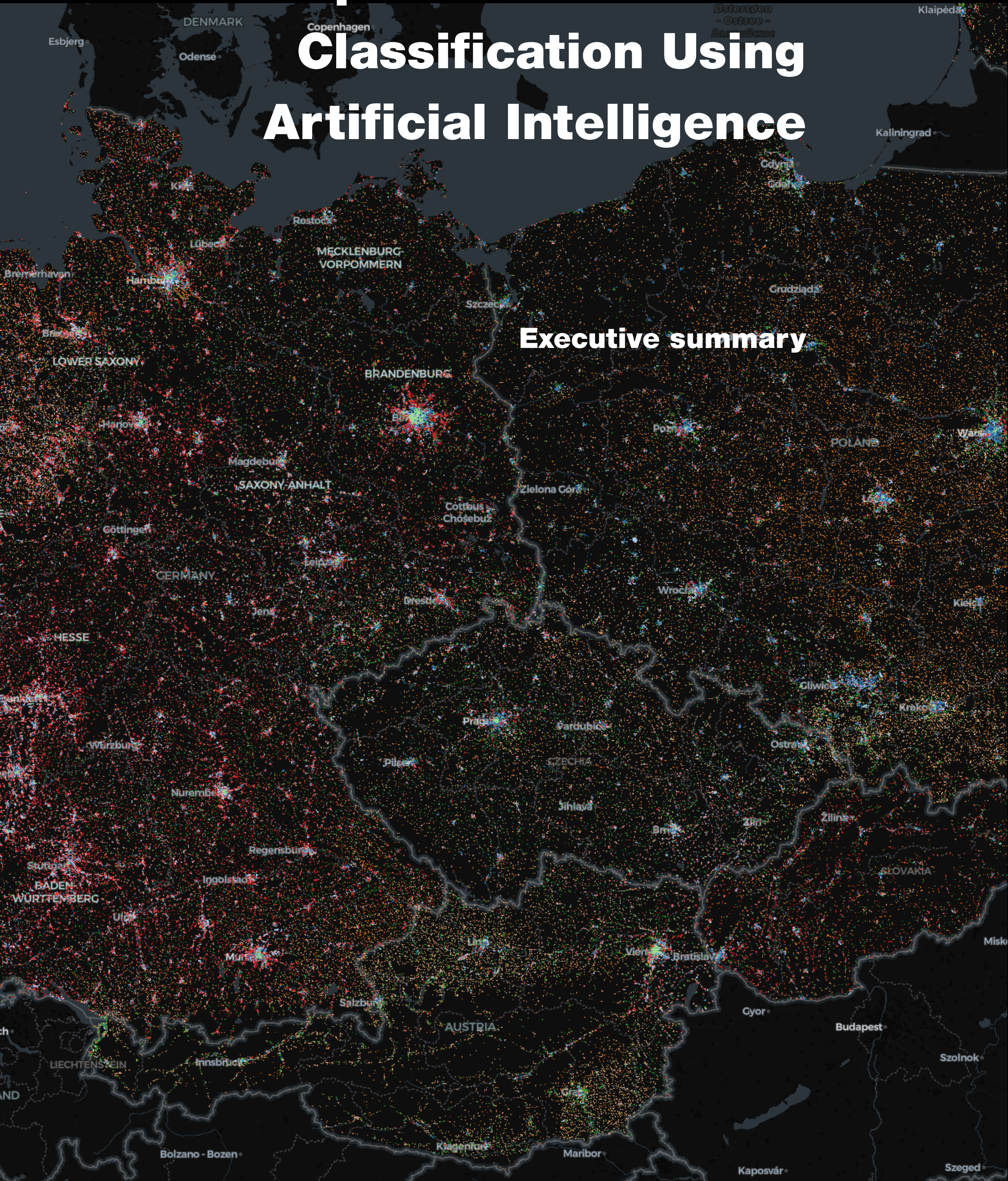
European Urban Fabric Classification Using Artificial Intelligence

Executive summary



EuroFab: European Urban Fabric Classification Using Artificial Intelligence

Executive summary

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This report details the outcomes of the EuroFab project, a research initiative funded by the European Space Agency (ESA) aimed at developing and implementing innovative methodologies for classifying European urban fabric using artificial intelligence (AI). The project addressed the critical need for accurate, consistent, and scalable methods for understanding and characterising the complex spatial structures of urban areas across Europe. By leveraging advanced machine learning techniques, deep learning and Earth observation data, EuroFab provides the methodological foundation for a detailed pan-European classification of urban fabric across time.

The project was structured around two primary methodological approaches: a morphological machine learning model utilising open vector datasets capturing physical structure of cities and an AI-based classification system employing satellite imagery.

Morphological Machine Learning Model: This component focused on developing a set of models able to transfer a taxonomic classification of urban form, based on quantitative morphometric characteristics from optimal cadastral data, to suboptimal building footprints of remote sensing origin (Microsoft Building footprints) and to heterogenous building data (Overture Maps). A detailed data pipeline was established to extract and process morphological data, predicting morphological types that capture the intricate patterns of urban layouts across Central Europe. Ground truth classes were derived from an existing morphometric classification generated on top of cadastral data, which yields optimal data accuracy but is limited in spatial coverage (Fleischmann and Samardzhiev Forthcoming). Two models were developed to predict the classes from either of the data sources, with the evaluation focusing on the of ability of the models to capture the individual classes across multiple resolutions and unseen contexts. The results indicate the ability of such models to fill the gaps in openly available cadastral data and showcase the potential of the approach to deliver pan-European classification of urban fabric as a combination of morphological processing and predictive modelling.

AI-Based Urban Fabric Classification using Satellite Imagery: The second major component of the project focused on utilising the information contained within openly available satellite imagery for urban fabric classification. This allows prediction of individual classes in various points in time and extending the morphological classification into a time-series with a potential for yearly updates. The project verified the approach in the case of prediction of spatial signatures of Great Britain (Fleischmann and Arribas-Bel 2022) using Sentinel-2 cloud-free mosaics. The project explored both classification and segmentation approaches, considering the optimal scale and sampling strategies for effective model training. At the same time, multiple geospatial foundation models were tested to understand their ability to capture intricacies of urban fabric.

A significant aspect of this work involved addressing the challenge of class imbalance, primarily caused by the extremely unequal spatial distribution of target classes naturally stemming from the gradual urbanisation processes. The final AI model demonstrated promising results in accurately classifying urban areas based on satellite imagery, offering a scalable and efficient alternative to traditional methods, albeit with a requirement of a certain degree of generalisation of original classification.

Furthermore, the project incorporated a temporal aspect, utilising the developed classification methodologies to examine changes in urban fabric over time. The Shannon Diversity Index was employed to quantify urban diversity, and spatial patterns of change were analysed to identify key trends and transformations across Great Britain. This temporal perspective provides crucial information for understanding urban development dynamics and their environmental and social implications.

Stakeholder Engagement: Recognising the importance of translating research findings into practical applications, the EuroFab project actively engaged with relevant stakeholders throughout its lifecycle. This included consultations with urban planners, policymakers, and municipalities to ensure the relevance and usability of the developed classification systems. Feedback from these engagements informed the refinement of the methodologies and the development of user-friendly outputs.

Key Findings and Lessons Learned: The EuroFab project yielded several key findings that advance our understanding of European urban fabric:

- The morphological machine learning model demonstrated the effectiveness of predictive infill of the classification based on suboptimal data in areas where the potentially optimal cadastral data is either not available as open data or is inconsistent with the majority of the other data.
- The AI-based classification system utilising satellite imagery offers a scalable and efficient approach for mapping urban fabric across large areas, with the potential for regular updates and monitoring.
- Addressing class imbalance is crucial for achieving accurate and representative urban fabric classification using satellite data.
- Temporal analysis using the developed methodologies provides valuable insights into urban development patterns and changes in urban diversity.
- Active stakeholder engagement is essential for ensuring the practical relevance and adoption of research outcomes in urban planning and policy.

The project also identified several important lessons learned, including the need for high-quality and consistently labeled ground truth data, the challenges of transferring models across different geographical contexts, and the importance of considering the interpretability of AI models for urban planning applications.

Potential Research Directions: Building upon the success of the EuroFab project, several potential avenues for future research have been identified:

- Further extension of the urban fabric classification to cover all the available cadastral data, ensuring the models have extensive geographical coverage of training data enabling continent-wide deployment.

- Development of modelling approaches combining both vector and raster data inputs to further enhance the gap-filling capabilities of predictive models.
- Application of the developed methodologies for specific urban challenges, such as heat island mapping, green infrastructure planning, and sustainable urban development.
- Expansion of the temporal analysis to investigate the impacts of specific policies and interventions on urban fabric change.
- Finally, scaling the analysis across the whole European space.

Conclusion: The EuroFab project has successfully developed and demonstrated innovative AI-based methodologies for classifying European urban fabric. The findings of this research provide valuable tools and insights for a wide range of applications in urban planning, environmental management, and policy development. By leveraging the power of artificial intelligence and Earth observation data, EuroFab contributes significantly to our ability to understand, monitor, and sustainably manage the complex and evolving urban landscapes of Europe. The project's emphasis on open science and stakeholder engagement ensures that its outcomes can be widely disseminated and effectively utilised by the broader urban research and practice communities.

References

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