Investigate Geographical Generalizability of GeoAI Methods for OpenStreetMap Missing Building Detection

by **JIAPAN WANG**

Aiming to improve mapping efficiency and reduce volunteer efforts for OSM building mapping, this study proposed a Geographic Weighted Model Ensemble (GWME) method for cross-country OSM building detection tasks. The promising results shed inspiring light on improving the generalizability and replicability of GeoAI models across geographic space [1,2]. Additionally, this study demonstrates a framework called GeoAI as a containerized microservice (GeoAIaaS), which utilizes microservice-based architecture with pre-defined mission recipes for handling geospatial data to lower the additional geography expertise barrier and improve the reusability of GeoAI solutions for web mapping applications.

INTRODUCTION

Keeping OSM data up-to-date and complete in the whole world is an essential mission for the mapping community. The emergence of novel deep learning networks over the past few decades, together with multi-sourced geospatial big data, has greatly contributed to the development of GeoAI, which has shown opportunities for supporting automatic mapping. When adapting pre-trained AI models to tackle geographic tasks, striking a balance between geographic generalizability and spatial heterogeneity of the model's performance remains a key challenge. Therefore, this study aims to improve the geographic generalizability of OSM building detection models across different African regions.

RESEARCH OBJECTIVES

RO1: To implement Geospatial Artificial Intelligence (GeoAI) methods, which can be well-generalized for OpenStreetMap missing buildings detection across geographical space.

RO2: Design a GeoAI web application to efficiently manage, evaluate, and visualize machine-generated geographic content.

METHODOLOGY

Geographic Weighted Model Ensemble

The GWME method (Fig. 1) began with training a Single-Shot Multibox Detection (SSD) base model for OSM missing building detection in the source region and transferring this base model to a set of reference areas surrounding the target region by multiple times Few-Shot Transfer Learning (FSTL) [2], eventually ensemble multiple FSTL predictions according to unique weights, which represents the importance of reference areas to the target area. The determination of weights uses a pre-trained Vision Transformer model [3] to simultaneously consider both context and relative location information, called self-attention weights, compared with the other three weighting approaches (average, image similarity, and geographical distance).

GeoAI as a Service

In order to efficiently visualize the predicted building locations for OSM, a GeoAIaaS web mapping application was designed to integrate GeoAI solutions (Fig. 2). It consists of three major parts:

Frontend: A user-friendly and intuitive portal to let users interact with maps.

Backend: Responsible for handling server-side functionalities that support data management, communication, and API Exposure.

Microservice: Provides modular, scalable, reusable, and distributed developable geospatial data analysis services, including different phases of a GeoAI workflow.

EXPERIMENTS

This study uses training samples (6272 buildings, 1744 tiles) from a well-mapped area in Tanzania to train the base model and selects a remote area in Cameroon as the target area (1811 buildings, 343 tiles) that does not provide any training samples. Eight reference areas were identified with few-shot training samples (5 – 10 tiles). The OSM missing building detection task was divided into three main steps: 1) Multiple few-shot predictions by FSTL models. 2) Weight computing via diverse weighting strategies. 3) Weighted model ensemble and evaluation. Experiments showed self-attention-based weighted model ensemble method achieved the highest performance with a 96.95% precision, 78.99% recall, and 0.8705 F1 score (Fig. 3).

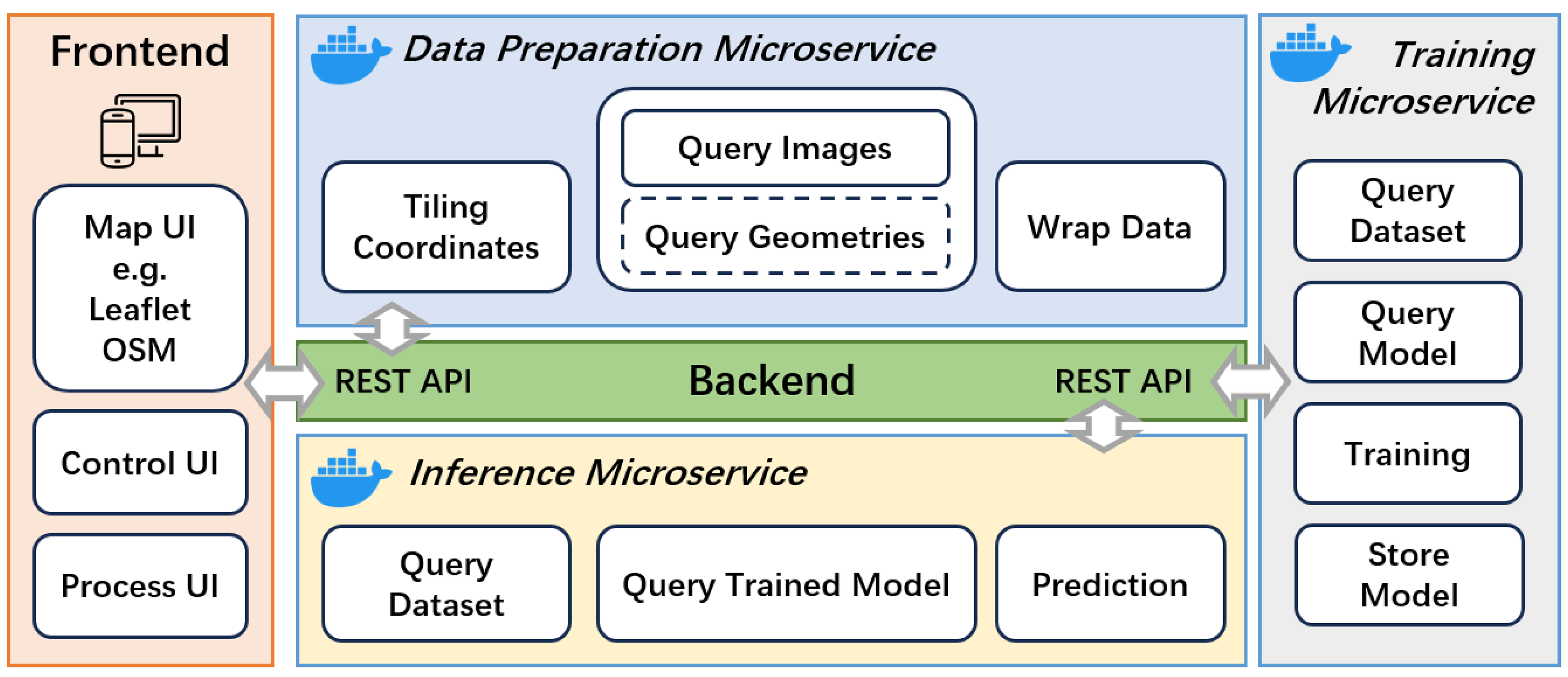

Fig.2 GeoAI as a Containerized Microservice (GeoAIaaS)

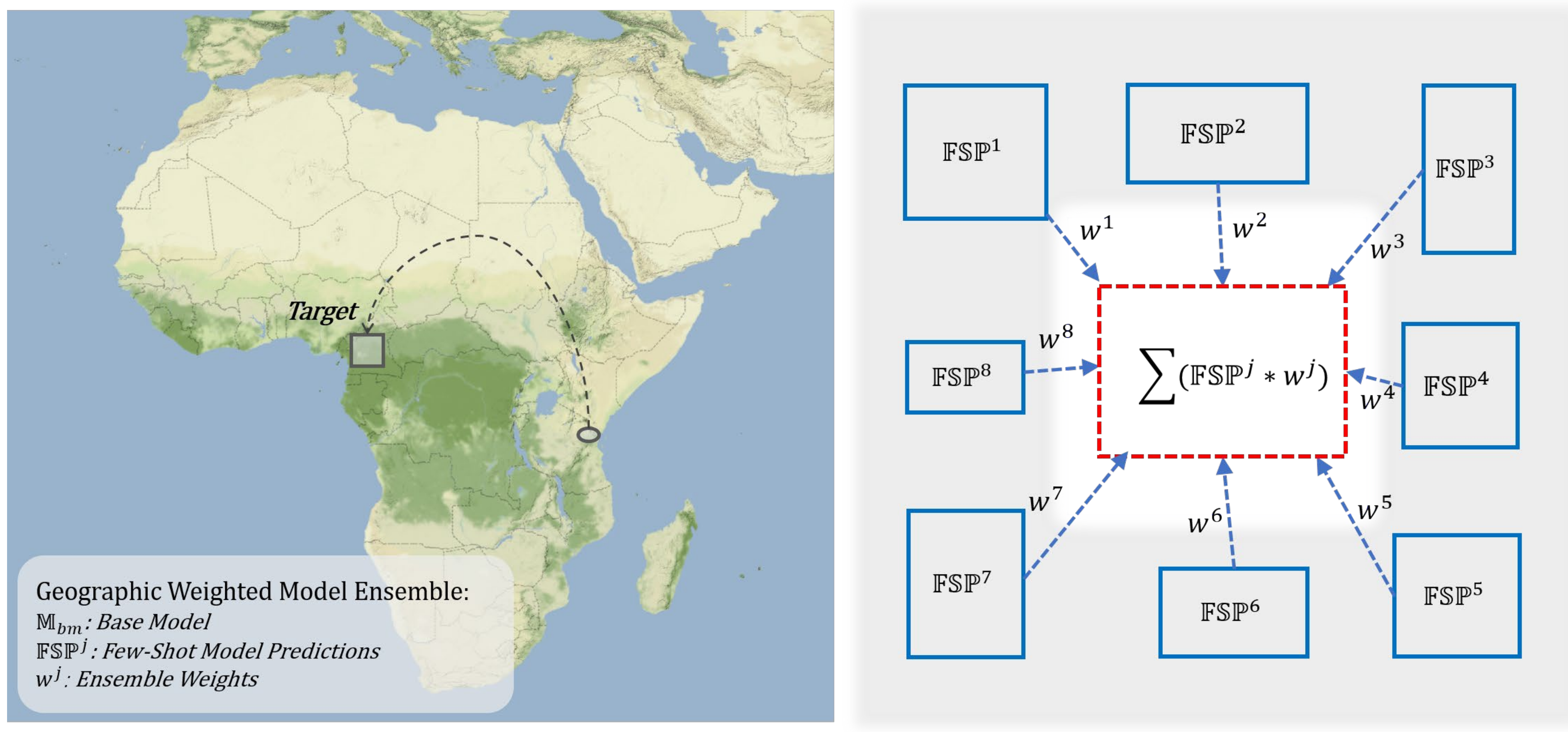

Fig.1 An overview of Geographic Weighted Model Ensemble (GWME)

CONCLUSION

This study proposed a GWME method to improve the geographical generalizability of building detection models across diverse regions and conducted experiments to confirm that self-attention-based weights outperform other methods. A microservice-based GeoAIaaS infrastructure was used to develop and deploy a GeoAI web mapping application providing visualization, inferencing, and comparing functions for OSM missing building detection tasks.

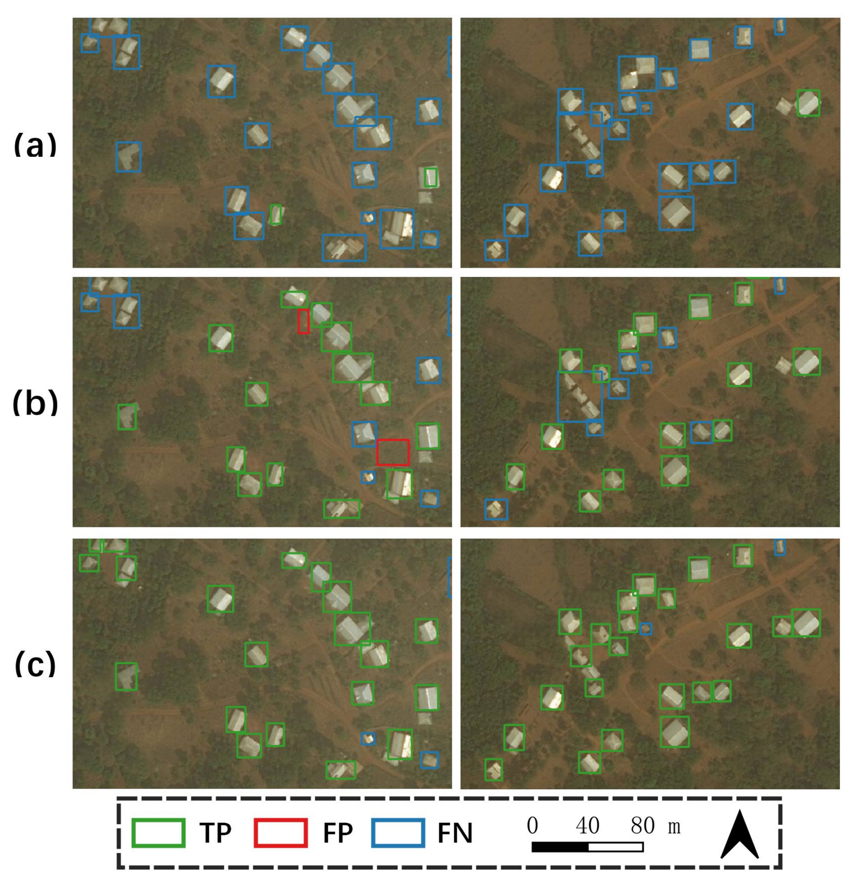

Fig.3 The comparison of prediction results. (a) the base model; (b) the single FSTL model; (c) the GWME result with self-attention-based weights.

THESIS CONDUCTED AT

Chair of Cartography
Department of Aerospace and Geodesy
Technische Universität München

Technische Universität München

THESIS ASSESSMENT BOARD

Chair Professor: Prof. Dr. Liqiu Meng, TUM
Supervisor: Dr. Hao Li, TUM
Reviewer: Assoc. Prof. Dr. Rolf de By, UT

YEAR

2023

KEYWORDS

GeoAI, OpenStreetMap, Model Ensemble, Object Detection, Microservice

REFERENCES

[1] Mai, G., Huang, W., Sun, J., Song, S., Mishra, D., Liu, N., Gao, S., Liu, T., Cong, G., Hu, Y., Cundy, C., Li, Z., Zhu, R., & Lao, N. (2023, April 13). On the Opportunities and Challenges of Foundation Models for Geospatial Artificial Intelligence. arXiv: 2304.06798 [cs]. https://doi.org/10.48550/arXiv.2304.06798

[2] Li, H., Herfort, B., Lautenbach, S., Chen, J., & Zipf, A. (2022). Improving OpenStreetMap missing building detection using few-shot transfer learning in sub-Saharan Africa. Transactions in GIS, 26(8), 3125–3146. https://doi.org/ 10.1111/tgis.12941

[3] Caron, M., Touvron, H., Misra, I., Jégou, H., Mairal, J., Bojanowski, P., & Joulin, A. (2021, May 24). Emerging Properties in Self-Supervised Vision Transformers. arXiv: 2104.14294 [cs]. https://doi.org/10.48550/arXiv.2104.14294

This master thesis was created within the Cartography M.Sc. programme – proudly co-funded by the Erasmus+ Programme of the European Union.

Technische Universität München | TU Wien Technische Universität Wien | Technische Universität Dresden | University of Twente. ITC | Erasmus+ | cartographymaster.eu