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Evolution, Trends, and Challenges of GeoAI in Cartography: A Systematic Review during the period 2000-2024

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Abstract:

Over the last years, Geospatial Artificial Intelligence (GeoAI) applications have had a significant impact on the cartographic community. In practice, GeoAI approaches aim to address traditional cartographic challenges (e.g., map design, cartographic generalization, and feature extraction) by utilizing big geospatial data (Boutayeb et al., 2025) and incorporating the modern nature of cartographic products, such as multi-scale maps and VR/AR environments. The growing interest within the community is evident from the fact that recent studies have aimed to identify existing trends and challenges both in the general field of cartography (Robinson et al., 2023; Kang et al., 2024; 2025) and in specific research areas (Zhou et al., 2025), while also considering ethical issues (Zhao and Lin, 2025; Kang and Wang, 2026) associated with the rapid expansion of GeoAI in cartographic workflows.

The present study aims to provide a systematic review of the integration of GeoAI in the field of cartography over a 25-year period (from 2000 to 2024). Specifically, the research identifies key scientific journals through an analysis of the temporal evolution of scholarly interest in AI-based approaches to cartographic problems. Based on the examination of core thematic areas and applications, the study further categorizes the most commonly used AI models, their respective training methodologies, and the diverse geospatial datasets utilized in their development. Finally, the analysis investigates the specific cartographic scales that have dominated research to date, aiming to synthesize these findings to highlight existing gaps and propose future research directions for the GeoAI community.

The methodology employed a two-phase, systematic search approach based on specific keyword queries (Kang et al., 2024). During the first phase, a broad search was conducted across prominent academic databases, such as Google Scholar and Scopus, utilizing Boolean operators to identify literature at the intersection of cartography and AI. Indicative keywords used at this stage included “cartography”, “map”, “mapping”, “AI”, “machine learning”, and “deep learning”. This initial stage yielded 108 sources, which was further supplemented by targeted searches of specific authors and journals. In the second phase, the literature was categorized according to the GIS&T Body of Knowledge (BoK, https://www.ucgis.org/site/gis-t-body-of-knowledge) thematic topics, with the core ones being “data”, “map design”, “map production” and “map use”. These topics guided a second round of Boolean queries, which incorporated specialized searches and an extra set of topic-related keywords alongside the initial ones (e.g., “map reading” for map use-related literature). The second round of research expanded the collection to 162 items. All documents were evaluated for relevance based on their titles, keywords, and abstracts. Following a rigorous screening for document type (peer-reviewed articles, reviews, and editorials) and thematic alignment, a final corpus of 60 core publications was selected for detailed analysis.

The results indicate a concentrated publishing environment, with Taylor & Francis (48%) appearing as the dominant venue, followed by a variety of other academic publishers. Scholarly interest has grown substantially since 2018, reaching distinct peaks in 2020 and 2024. The thematic (topic-based) analysis reveals that map design is the dominant research area (42%), with a significant focus on automating cartographic generalization and multiscale data (76% of the category). Most studies prioritize large-scale representations (from neighbourhood to regional levels) since these scales require complex, automated generalization tasks that GeoAI models are designed to address. In contrast, small-scale maps (equal or larger than 1:750,000) have been significantly less explored. Technical evaluation shows that supervised learning and raster-based data formats prevail, often requiring the conversion of vector inputs into images for model compatibility. However, AI processing pipelines and learning paradigms are becoming increasingly diverse over time, especially when taking into account the shift of researchers’ interest on the thematic areas. Architectures like Convolutional Neural Networks (CNNs) have dominated data collection and map reading since the early 2020s, while models such as

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Generative Adversarial Networks (GANs) and Large Language Models (LLMs) have recently emerged to provide more holistic solutions for automated map synthesis. Training methodologies vary as well. Unsupervised learning is the primary choice for map use applications, while Reinforcement Learning (RL) is applied to map layout optimization and, occasionally, in data mining applications. Finally, there is a growing reliance on a combination of quantitative metrics (e.g., F1 score) and qualitative visual assessments by experts to ensure cartographic integrity. This highlights existing research gaps and proposes future directions for the GeoAI community.

Based on the literature review and analysis, several key issues were identified. One major issue is the lack of high-quality, compatible datasets for training AI models. Hence, researchers often rely on synthetic data from GANs or crowdsourced data from open platforms, such as OpenStreetMap. However, these methods can introduce several reliability issues. Technical performance is also affected by map symbology; complex layers often lead to lower accuracy. Moreover, a lack of the so-called "transfer learning" techniques (Touya et. al., 2019) is observed in current models, leading to decreased performance when parameters such as dataset, area of interest and scale change. In addition, many AI architectures lack cartographic reasoning, resulting in errors in topological rules and aesthetic standards. These challenges could be addressed by focusing on Explainable AI (XAI) and foundation models, such as MapGPT (Zhang et al., 2024). Future models could process vector-based inputs directly to avoid errors caused by rasterization. Additionally, more research is needed on small-scale map products, which are currently inadequately represented. Finally, ethical issues, such as bias and computational accessibility, must be addressed by the cartographic society.

Future work includes the development of a dynamic, web-based platform for presenting and analyzing the reviewed literature towards further enhancing the accessibility of these findings. This platform could utilize interactive tools (e.g., VOSviewer (Wong et al., 2018) bibliometric network data tool) to provide a visual and exploratory environment for navigating the evolving landscape of GeoAI in cartography. Furthermore, the platform could incorporate automated mechanisms for identifying relevant scholarly articles and highlighting open-access datasets, creating a continuous, self-updating repository to foster collaborative research and open-science initiatives within the cartographic community.

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