

REVIEW OF EMERGING TRENDS OF ARTIFICIAL INTELLIGENCE (AI) IN GEOGRAPHICAL RESEARCH

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Abstract

Artificial Intelligence (AI) is rapidly transforming geographical research by enhancing spatial analysis, modelling, and decision-making processes. The present systematic review synthesizes recent literature on emerging trends in AI applications within Geography. The study highlights key domains such as geospatial data analysis, remote sensing image classification, land-use and land-cover mapping, urban planning, climate change assessment, disaster management, and precision agriculture. Integration of AI with Geographic Information Systems (GIS), Global Positioning Systems (GPS), and Earth observation technologies has enabled automated spatial modelling, real-time monitoring, and predictive analysis. For the purpose of systematic review of AI in geography various research articles have been collected from google scholar, IEEE Xplore, Science Direct, Research Gate, Shodhganga and E -Shodh-Sindhu. The present review included to identify the methodologies used for the data process and shift of traditional methods of analyses from statistical techniques to machine and deep learning. It is observed that AI provides remarkable accuracy and efficiency in data processing.

Keywords: Artificial Intelligence, Geospatial Data, Remote Sensing, Deep Learning, Machine Learning.

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Introduction:

Artificial intelligence (AI) is currently receiving remarkable attention from industry, government, the general public, and academia. Since its beginning in the 1950s, AI has been a broad field with different definitions depending on the research goals (Russell & Norvig, 2003). The 2000s saw ML becoming more wide spread within geography and other disciplines as unsupervised methods enabled the analysis of large data sets. More recently, deep learning emerged to enable processes to be integrated into many software services and applications. (Lavallin & Downs 2021). This paper comprehensive reviews the use of AI in different fields of geography. The review also examines methodological shifts from traditional statistical techniques to machine learning and deep learning frameworks in spatial sciences. While AI offers improved accuracy and efficiency, challenges including data quality, algorithmic bias, ethical concerns, and digital inequality persist. The study concludes by emphasizing interdisciplinary collaboration and responsible AI adoption to ensure sustainable and inclusive geographical research and spatial development in the future.

Objective:

“The primary objective of this review article is to analyse global scholarly contributions regarding the application of Artificial Intelligence (AI) across various subfields of geography and to identify future opportunities for AI integration within the discipline.”

Data & Methodology:

Data were synthesized from several prominent academic databases, including Google Scholar, IEEE Xplore, ScienceDirect, ResearchGate, Shodhganga, and e-ShodhSindhu, with a focus on peer-reviewed journals. While identifying current trends and challenges within the broader AI sector, the selection was strictly narrowed down to papers directly relevant to the field of geography.

Discussion:

Following 25 articles have been reviewed and main thrust and methodology has been discussed chronologically as below. For the purpose most recent articles have been reviewed.

McKeown, David M. (2007) Discusses how techniques from the AI community can expand the scope of Geographic Information Systems (GIS) by addressing deficiencies in user interfaces, spatial data representation, and utilization. Authors proposes extending the concept of a GIS to actively include remotely sensed imagery and details the necessary image-to-map correspondence capabilities to integrate images, maps, terrain, and external map data. The authors draw on ongoing research at Carnegie Mellon University, including the MAPS system, as an example of utilizing AI techniques in image/map databases and knowledge-based image interpretation.

VoPham, Trang, et al. (2018) Defines Geospatial Artificial Intelligence (geoAI) as an emerging scientific discipline combining spatial science, AI methods (like machine learning and deep learning), data mining, and high-performance computing to extract knowledge from spatial big data. The present paper thoroughly explains the application of geoAI technologies in environmental epidemiology, specifically for exposure modelling and assessment, highlighting advantages such as incorporating large amounts of spatiotemporal data and computational efficiency. This endeavour presents an overview of key concepts surrounding the interdisciplinary field of geoAI, including spatial data science, machine learning, deep learning, and data mining, along with recent research applications.

Sidiq, S. Jahangeer, Majid Zaman, and Muheet Ahmed (2019): This review paper presents an introduction to the implementation of machine learning on geographical dataset: How it started, how much has been achieved and what is current scenario of machine learning in geographical sciences. The main area covering in this paper are meteorological data, Ensemble models, regression, classification including Neural Networks, Support vector machine (SVM), Decision trees, Naïve Bayes, J48, CART, ID3. However, the main thrust area has been the implementation of various neural network models which includes BPNN, FFNN, GWLM-NARX, RNN, and TDNN in geographical data sciences.

Ivić, Majda (2019) Presents an overview of how artificial intelligence is utilized for geospatial analysis specifically within the context of disaster management. In the article authors explains that AI tools are increasingly employed for quicker and enhanced integration and analysis of spatial data, which is crucial for rapid response and recovery after a catastrophe. Details have been given, how AI algorithms, such as those inspired by artificial neural networks, are applied to analyse spatial data from various sources (e.g., satellite imagery, drone imagery, sensor data) in real-time or near real-time.

Kiwelekar, Arvind W., et al. (2020) The present publication examines the current state of applications using deep learning techniques for analysing geospatial data, including remote sensing, GPS, and RFID data analytics. The details about deep learning for geospatial tasks has been discussed. The deep learning techniques, such as Neural Networks, offer effective solutions for various geospatial data analysis tasks like object recognition, image classification, and scene understanding, often outperforming conventional machine learning methods.

Present work also explains the generation of vast amounts of location-enriched geospatial data from consumer electronic devices and sensors, which is being leveraged for civilian applications such as recommendation systems, traffic monitoring, and weather reporting.

Janowicz, Krzysztof, et al. (2020) The present endeavour Explains GeoAI as a subfield of spatial data science that uses advancements in AI techniques and data cultures to support the creation of more intelligent geographic information and methods for various downstream tasks, such as object detection, scene segmentation, and spatial interpolation. This work demonstrates the application of AI techniques in geography through examples like detecting terrain features and building footprints, extracting information from historical maps, and semantic classification of LiDAR point clouds. The study discusses the importance of spatially explicit models in applying AI and data science techniques to spatial data, noting that these models substantially outperform more general models when applied to spatial data.

Lavallin, Abigail, and Joni A. Downs (2021) Explains the emergence of Geo-AI, a new discipline resulting from the integration of Artificial Intelligence (AI) into geography, particularly GI Science, Geographic Information Systems (GIS), and remote sensing. The study reveals details the increasing use of Machine Learning (ML) within geography, noting that unsupervised methods have enabled the analysis of large data sets since the 2000s, and Deep Learning has more recently been integrated into software services and applications.

Present study cites examples of current applications of Deep Learning in geographical questions, including evaluating points of interest using social media geo-tags, location-based advertising, and landslide susceptibility mapping and predictions.

Zhang, Lefei, and Liangpei Zhang (2022) Reviews the recent achievements of AI algorithms and applications specifically in Remote Sensing (RS) data analysis, which is a key component of geospatial technology. The review article Covers major aspects of AI innovation for RS, including machine learning, computational intelligence, AI explicability, data mining, and Natural Language Processing (NLP).

The authors of the review discuss the increasing use of AI approaches within the IEEE Geoscience and Remote Sensing Society (GRSS) to extract information and knowledge, directly linking AI to geospatial fields.

Li, Wenwen, and Chia-Yu Hsu. (2022) Reviews the field of Geo-AI, or geospatial artificial intelligence, as the frontier for spatial analytics in Geography. The present review article provides a comprehensive overview of Geo-AI research used in large-scale image analysis, covering methodological foundations and recent progress in geospatial applications. The authors organize the review of Geo-AI research based on different data types, such as satellite and drone images, street views, and geo-scientific data, and their applications in various image analysis and machine vision tasks.

Sahana, K. S., et al (2022) The present article introduces Geo-AI as an emerging research area that integrates AI technology with various Geographic Information System (GIS) techniques, directly addressing the use of AI and geospatial technology. Article discusses the potential of Geo-

AI to transform geography and geomatics programs by incorporating a Geo-AI dimension into modern GIS curricula, showing the overlap of these fields.

It reviews the application of Geo-AI in various healthcare fields, such as disease diagnosis, public health surveillance, and infectious disease control, illustrating specific uses of this combined technology.

Abdurakhmonov, Sarvar, et al (2023) Reviews the most recent advancements in cartography, a key component of geography, emphasizing techniques like GIS, remote sensing, data visualization, and web-based mapping. Endeavour covers the growing application of machine learning algorithms in cartography for analysing large datasets and identifying hidden patterns, leading to more accurate and detailed maps. The article further discusses how machine learning techniques can be applied to practical geographic problems, such as identifying traffic flow patterns to create more efficient transportation routes.

Choi, Yosoon (2023) Explores the integration of Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) with Geographic Information Systems (GIS), which allows for the collection, analysis, and visualization of spatial data. Authors presents a collection of research papers that apply AI, ML, and DL to various geospatial topics, including image classification, object detection, land cover mapping, and urban growth prediction. Article further explained the development of new methods using AI to process and analyse large spatial datasets, improving the accuracy and efficiency of tasks compared to traditional GIS methods.

Emami, Payam, and Ameneh Marzban (2023) In their article explains how integrating Artificial Intelligence into Geographic Information Systems can revolutionize disaster management by improving efficiency and decision-making. They discuss how AI algorithms enhance GIS capabilities through automated data processing, pattern recognition, and predictive modelling for future disaster impacts. The application of AI in real-time monitoring, early warning systems, disaster response, recovery efforts, and damage assessment by analysing various geospatial data sources have been discussed in detail.

Raihan, Asif (2023) In his article reviews the application of Deep Learning (DL) techniques in Geographical Information Systems (GIS), covering fundamental DL concepts relevant to GIS and focusing on current research findings. The present review article Investigates the uses of remote sensing technology in various domains, including mapping, hydrological modelling, disaster management, and transportation route planning. The review article further Discusses the potential of integrating DL with GIS to gain novel insights into environmental phenomena by utilizing capabilities in spatial, temporal, and spectral resolutions and data integration.

Song, Yongze, et al (2023) Explains the essential roles of geo - computation and geospatial artificial intelligence (Geo-AI) in advancing geographic information science (GIS) and Earth observation. The Study provides a comprehensive overview of Geo-AI applications in mapping, categorized into buildings and infrastructure, land use analysis, natural environment and hazards, and social issues and human activities.

The article summarizes the types of geospatial and Earth data utilized in Geo-AI studies, including remote sensing, crowdsourced data, LiDAR, and statistical data.

Srivastava, Nishi, and Nisheeth Saxena (2023) in their article explains how the advancement of AI and powerful computing resources have led to significant progress in geographic analysis for environmental applications. Authers given details how AI has reshaped the research environment, enabling high-resolution geospatial analytics. Present article notes that AI serves as an alternative and more effective method for handling the big data generated by high-resolution remote sensing and other environmental sensors.

Janga, Bhargavi, et al (2023) Synthesizes existing literature on Artificial Intelligence (AI) applications in remote sensing, consolidating, and analysing AI methodologies, outcomes, and limitations. Further the study explores diverse applications of AI in remote sensing, including image classification, land cover mapping, object detection, change detection, hyperspectral and radar data analysis, and data fusion, which are relevant to geography and geospatial technology. The study also presents an overview of remote sensing technologies, methods employed, and relevant use cases, thereby detailing the integration of geospatial technology with AI.

Zhou, Tianyi (2023) Explores the application of various machine learning methods in diverse geographical environments, including the atmosphere, geology, hydrology, natural disasters, urban and rural planning, agricultural production, and tourism geography. The present article focuses on the use of artificial intelligence in areas like Geographic Information Systems (GIS), Remote Sensing (RS), and the Beidou Navigation Satellite System.

In the present study Zhou, Tianyi used AI algorithms are discussed. Summarizes the use of algorithms such as random forest, neural networks, and expert systems in physical geography, human geography, and geographic information systems.

Ahmed, Zakaria Yehia (2024) Explains the concept of Geo-AI, which integrates artificial intelligence with Geographic Information Systems (GIS) operations, including geospatial machine learning and geospatial deep learning. The study focuses on, how AI for GIS applies AI techniques to enhance GIS software capabilities, such as AI attribute collection, AI survey and mapping, AI cartography, and AI interaction.

The present study discussed how GIS for AI utilizes GIS capabilities, such as geographical visualization and spatial analytics, to further process and enhance data obtained from AI recognition for applications like traffic flow monitoring and city component management.

Gu, Zhujun, and Maimai Zeng (2024) Reviews the methods for assessing Land Cover Change Detection (LCCD) using artificial intelligence (AI) and satellite remote sensing, focusing on advanced AI technology applications. The study comprehensively discusses the significant applications of AI and remote sensing image analysis for LCCD, which is a key topic in physical geography and environmental monitoring. The study also analyses current challenges in LCCD and proposes future research directions, such as leveraging explainable AI and utilizing point-clouds for improved description of objects in satellite images.

Harrie, Lars, et al. (2024) Explains the increasing use of machine learning as a computing paradigm in cartographic research, which falls under the umbrella of geography and geospatial technology. Authors discusses specific cartographic applications where machine learning is utilized, including pattern recognition in maps, cartographic generalization, style transfer, and map labelling. The present paper addresses the role of map encodings for machine learning applications and the potential requirement for explicit cartographic knowledge and procedural modelling in these AI models.

Nistor, Andrei (2024) evaluate the advancements, applications, and implications of integrating artificial intelligence with geospatial technologies across sectors like urban planning, transportation, environmental monitoring, and disaster management. The authors in their work present application of three detailed case studies—tourism accommodation and transportation hubs, air quality monitoring, and satellite image classification—demonstrating the enhanced capabilities offered by AI-geospatial integration.

In the present study authors adopts a situational composition methodology tailored for geospatial projects, including problem identification, method selection, and implementation, considering factors like data quality and ethical considerations.

Siddique, Iqtiaar (2024) Explores the synergy between machine learning (AI) and Geographic Information Systems (GIS), highlighting their combined potential to unlock new insights from spatial data and enhance predictive modelling. Authors genuinely addressed complex spatial challenges through machine learning algorithms like neural networks, random forests, and support vector machines for tasks such as land cover classification, urban growth modelling, environmental monitoring, and disaster response. Authors shown the practical applications of machine learning in GIS through illustrative case studies and examples across diverse domains.

Saleh, Huda Jassim Haseeb, Judith Ratu Tandi Arrang, and Luis Miguel Oliveira de Barros Cardoso (2025) Explains the concept of “Geo-AI” as the intersection of artificial intelligence, spatial science, and big data analytics, particularly in relation to geographic challenges. The study reviews the key applications of Geo-AI in human geography and spatial networks, including fields like urban planning, population mobility, social network analysis, and health geography. The article widely describes the methodologies and enabling geospatial technologies used in Geo-AI, such as machine learning, deep learning, graph neural networks, GIS, remote sensing, and spatial databases.

Zhou, Bing, et al. (2025) Explains how Natural Language Processing (NLP), a branch of Artificial Intelligence, can be integrated into human geography for knowledge discovery from geographic narratives and geoparsing from texts. Demonstrates the use of NLP techniques in human geography through two AI case studies related to COVID-19, including locating vulnerable communities and analysing public emotions using sentiment analysis on social media data. The authors in the present study Highlights the use of geoparsing tools to extract geographic information from unstructured textual data, facilitating geospatial data enrichment and near real-time information retrieval for spatial analysis.

Conclusion:

In conclusion, this review highlights the transformative impact of Artificial Intelligence across diverse geographical subfields, from urban planning to environmental monitoring. By analysing contributions from major scholars, it is clear that AI is no longer just a tool, but a foundational element of geographical inquiry. The synthesis of global research reveals that while AI significantly enhances data processing and predictive accuracy. By bridging the gap between computational power and spatial theory, future research can move beyond simple automation toward a more profound, AI-driven understanding of complex Earth systems

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