JMI Jurnal Multidisiplin Indonesia

Volume 3 Nomor 1 Januari 2024
E-ISSN: 2963-2900 | P-ISSN: 2964-9048
https://jmi.rivierapublishing.id/index.php/rp

A REVIEW GEOSPATIAL ARTIFICIAL INTELLIGENCE (GEO-AI): IMPLEMENTATION OF MACHINE LEARNING ON URBAN PLANNING

Cholid Fauzi
Politeknik Negeri Bandung
Email: cholid.fauzi@polban.ac.id

Abstract

Geospatial Artificial Intelligence (Geo-AI) is an interesting topic in its development and application in our lives. One of them is spatial planning, which contributes to the economic and social development of a region or country. Spatial data is the main thing in this research, which maximizes the effectiveness of land use spatial data on the area as upstream data and develops GIS-based urban planning applications to display the results of analysis and predictions of urban objects automatically. On the other hand, to maximize tourism revenue, the government plans urban areas for both spatial and land use and makes a lot of spatial data based on geographical and environmental conditions. This study will analyze the benefits of Geo-AI in urban planning and the tourism sector. The method used in this study is the Systematic Literature Review (SLR), where the search for the required articles comes from electronic databases obtained using the NVivo software with article sources from Publish or Perish. This study discusses the main steps for the analysis of geospatial data that have been successful in the main areas, namely the development of applications and models, including visualization. By treating issues in geospatial artificial intelligence, the overall aim of the research is to improve the quality of life for Indonesia's growing urban population. The results of the study with the systematic literature review of Geo-AI found a gap in the research implementation of the machine learning model used where five models were compared and relevant to the geospatial dataset displayed in the form of a literature review matrix and visually included in the relevant keywords in the bibliometric analysis. Interdisciplinary results are developing and are urgently needed by both government and private stakeholders in the development of smart cities to prepare spatial planning in urban areas and strategies in optimizing technology in the field of spatial planning in implementing systems based on Geo-AI.

Keywords: *SLR. GIS. Geospatial Artificial Intelligence. Geo-AI. Machine Learning.*

Corresponding Author: *Cholid Fauzi*
E-mail: cholid.fauzi@polban.ac.id

Introduction

GeoAI, which is a field that is constantly evolving and aims to assist in the processing and spatial analysis of big data, can also be described as a new discipline that combines innovations in spatial science, AI methods such as Machine Learning (ML), and Deep Learning (DL), data mining (data mining), and high-performance computing (high-performance computing. According to Gartner, GeoAI is the use of artificial intelligence (AI) methods, including ML and DL (Pierdicca & Paolanti, 2022), to generate knowledge through spatial and image data analysis. The increasing availability of geographic data, the development of AI, and the availability of large computational capacities have all contributed to the increased significance and potential of GeoAI. This concept is fed into the larger AI framework as a sub-discipline of AI that uses machine learning to extract knowledge from geographic data. Geo-AI now has an important role to play in advancing traditional AI technologies and innovating new ways to solve specific problems posed by the massive, complex, diverse and ever-increasing nature of geospatial data, which is considered geo-referenced data containing geotagging locations or position markers. Geospatial data is widely used in many scientific fields and applications, including smart cities, transportation, business, public health, public safety, resilience to natural disasters, climate change and so on. The goal of tackling this problem is to improve the quality of life of the world's growing urban population (Cugurullo, 2020). Various disciplines are involved in shaping this interdisciplinary field, including computer science, geography, geographic information systems (GIS), and urban studies. The purpose of this study is to provide an overview of the main concepts surrounding the emerging field of GeoAI, Clarify the differences between GeoAI and more general AI, and Integrate AI with GIS, making visualization and software that have AI characteristics paramount. In addition, this study discusses the main steps for geospatial data analysis that have been successful in the main areas, namely application and model development, including visualization. By addressing issues in geospatial artificial intelligence (Alastal & Shaqfa, 2022), the overall aim of the research is to improve the quality of life for Indonesia's growing urban population.

Research Methods

Previous research was obtained before doing SLR. Alastal and Shaofa (Abelha, Fernandes, Mesquita, Seabra, & Ferreira-Oliveira, 2020) research an overview of GeoAI technology, including the definition of GeoAI and the differences between GeoAI and traditional AI. Key steps to successful geographic data analysis include integrating AI with GIS and using GeoAI tools and technologies. It also shows the main areas of application and models in GeoAI, as well as challenges to adopting GeoAI methods and technologies and their benefits. This article also includes a case study of using GeoAI in Kuwait, as well as some recommendations. W. Li and C. Y. Hsu (Alastal & Shaqfa, 2022) research based on various types of imagery or structured data, including satellite and drone imagery, street views, and geoscientific data, and their application to a variety of image analysis and machine vision tasks. While different applications tend to use different types of data and models, we summarize the six main strengths of GeoAI research, including (1) enablement of large-scale analytics, (2) automation, (3) high accuracy, (4) sensitivity in detecting subtle changes; (5) noise tolerance. K. Janowicz et al. (Janowicz, Gao, McKenzie, Hu, & Bhaduri, 2020) research on GeoAI for geographic knowledge discovery, explains how changes in data are driving the rapid growth of GeoAI and point out future research directions. It also describes the development of spatially explicit models and the sharing of high-quality geospatial datasets to advance GeoAI research that can be reproduced in future research. The research is based on two practical examples: how geospatial products can be generated in the proposed architecture, how these products can be used in machine learning for tactical planning, and how learned action courses and intelligence products can be provided to planners in decision support.

Results and Discussion

A. Identification

Significant work using SLRs in climate change studies was carried out by Berrang-Ford (Berrang-Ford, Pearce, & Ford, 2015). The authors adopted their recommendations for the SLR primarily for outlining the research questions and objectives, selecting data sources and documents, and analyzing and presenting results. The authors conducted a layered literature review to determine the inclusion and exclusion of findings that were more relevant to study publications using the Scopus research engine by publication no later than June 26, 2023, with a period from 2019 to 2023. Scopus was chosen because it has the largest database of peer-reviewed literature and the ability to search, find, and analyze. There is the first stage, the author uses the key research terms Geospatial Artificial Intelligence, Geo-AI, and Geospatial AI. The second stage involved exclusion further to refine the results in the previous literature review (Berrang-Ford et al., 2015). Exceptions include improvements to the field of study, namely urban planning and tourism, as well as types of documents and titles of sources that are not directly related to the topic. This resulted in 129 publications.

The final phase involves excluding those studies on tourism and urban topics that are covered under the topic of Geo AI in a very general scope and that touch on tourism and urban planning issues rather than specifically in Indonesia. Further exceptions are warranted when the author deems the scope too broad.

B. Screening

The author downloads the results in XML format, saves them, and imports them into Nvivo. When importing into Excel, the author selects all delimiters to make sure the information goes into the right columns. However, the results are only sometimes consistent, requiring manual checking of each entry line. The author found that the number of counts on the author's publications and citations presented in the Scopus search sometimes differed from the actual Excel sheet checks. Therefore, to ensure consistency, a higher number of publications and citations was chosen. Results in Excel format are checked line by line to determine exclusion from the list further. Finally, there are 38 ingredients selected.

C. Eligibility

In carrying out a qualitative synthesis in this stage using the Matrix Framework, by coding or codifying each literature and case in accordance with the findings related to the topics found, namely:

1. Title
2. Years
3. Methods and Models
4. Tools

D. Included (Meta-Analysis)

Geo-computation and Geospatial Artificial Intelligence (GeoAI) represent innovative approaches that promote better Geographic Information Systems (GIS) and Earth Observation. Geo-computation has the advantage of using computational methods and tools to explore geospatial data and earth data to generate new knowledge(Janowicz et al., 2020). Meanwhile, GeoAI provides learning algorithms and techniques, such as machine learning, deep learning (Li, 2021), and knowledge transfer, to develop effective and innovative solutions for geospatial and earth problems (PS Chauhan & Shekhar, 2021), (Pierdicca & Paolanti, 2022), (Liu & Biljecki, 2022). Mapping is an important component of GIS and earth observation, which helps in understanding the natural and built environment. Traditionally, spatial analysis based on spatial statistical inference theory is used for mapping. Spatial analysis issues can be classified into the following categories: identifying spatial patterns (Xu, 2021), exploring spatial factors(Liu & Biljecki, 2022), spatial simulation (Wen & Li, 2022), and geographic decision-making (Chadzynski et al., 2021). Despite differences in scope and focus, geo-computation and GeoAI have significantly advanced methods of geospatial analysis and mapping in recent years and have the potential to change the way we understand and manage the complex interactions between human and natural systems.

Geo-computation and GeoAI have advanced approaches to address complex geospatial and earth-related challenges. The integration of advanced computing tools provides more opportunities for innovative applications of geospatial artificial intelligence (GeoAI) and earth observation. These advanced computational tools include big data analysis (Song, Kalacska, Gašparović, Yao, & Najibi, 2023), cloud computing (such as Google Earth Engine) (Teja, Liu, & Chopra, 2023), graph knowledge (Nizzoli, Avvenuti, Tesconi, & Cresci, 2020), GeoAI has become a driving force in advancing geospatial data utilization. Even though the implementation of geo-computation and GeoAI in mapping is growing, there is still a need to improve application development from various perspectives. First, it is increasingly important to understand the geospatial implications of the methods and results generated by geo-computation and GeoAI, currently, from an algorithm or model perspective. Geo-computation and GeoAI largely involve applying computational methods and direct learning to geospatial data. This leads to a relatively simplified integration of geospatial characteristics and spatial associations in models.

Traditional spatial analysis techniques make use of various geospatial characteristics, such as spatial autocorrelation to measure similarity between observations (Arundel, Li, &

Wang, 2020), spatial heterogeneity to describe variations in geospatial data across space, spatial singularity and spatial anomalies to detect observations unusual and rare data and to measure similarity and complexity of geospatial data based on their respective geographic configurations. Although some recent studies have characterized spatial dependence using the relationship between data and their correlation (Wen & Li, 2022), the incorporation of these geospatial features still needs to be improved. In addition, geospatial data is complex and diverse, with sources and types as diverse as satellite imagery, aerial photographs, photogrammetric data, geospatial data, and location data from social media treated as samples or images like other fields, regardless of their geospatial features. Special. As we know, geospatial data and geospatial data can accurately describe geospatial information with various spatial types (e.g. points, polylines, areas and grids) and at different scales, apart from the location itself, such as longitude and latitude. Therefore, there is a need to integrate these unique geospatial features into GeoAI algorithms and models to fully utilize its capabilities in solving geospatial and geodata-related challenges. SLR contains a review of GeoAI and a collection of case studies that have been conducted, which have been classified into four categories: GeoAI Applications, Spatial Analysis, Methods and Models in GeoAI, and Tools. This case review categorizes applications in finding gaps in the GeoAI topic into these four categories, giving the reader a clear understanding of the case or issue presented in this study. In summary of the literature review

Based on the SLR process, selected articles are presented in categories that have been determined based on the results of the review of each article, in the article, there may be no mention of one of the categories, and articles with grey shading are review articles of the same type as in table 1.

Table 1
Selected articles based on the results of the review of each article

No	Authors	Title	Year	Method	Models	Tools
2	Vopham T, Hart JE, Laden F, Chiang YY	Emerging trends in geospatial artificial intelligence (geoAI): Potential applications for environmental epidemiology (VoPham, Hart, Laden, & Chiang, 2018)	2018	DL, ML	feature recognition in historical maps, multi-sensor remote sensing image resolution enhancement, and identification of the semantic similarity in VGI attributes for OpenStreetMap	Spark Hadoop
3	Janowicz K, Gao S, McKenzie G, Hu Y, Bhaduri B	GeoAI: spatially explicit artificial intelligence techniques for geographic knowledge discovery and beyond (Janowicz et al., 2020)	2020	DL, ML	spatially explicit models, question answering, and social sensing,	EarthCube, ESRI
4	Liu P, Biljecki F	A review of spatially-explicit GeoAI applications in Urban	2022	DL, ML	Deep neural networks and spatially-explicit GeoAI	ESRI

		Geography (Liu & Biljecki, 2022)				
5	Pierdicca R, Paolanti M	GeoAI: A review of artificial intelligence approaches for the interpretation of complex geomatics data (Pierdicca & Paolanti, 2022)	2022	DL	networks (DNNs), image segmentation model, Semantic segmentation, convolutional neural networks	red green–blue (RGB) images, thermal images, 3D point clouds, trajec- tories, and hyperspectral –multispectral images
7	Chadzynski A, Krdzavac N, Farazi F, Lim MQ, Li S, Grisiute A, Herthogs P, von Richthofen A, Cairns S, Kraft M	Semantic 3D City Database — An enabler for a dynamic geospatial knowledge graph (Chadzynski et al., 2021)	2021	DL, ML	dynamic geospatial knowledge graph	
8	Fischer MM	Spatial Analysis and Geo Computation: Selected Essays	2006	ML	spatially explicit models	CityGML 2.0
9	Yang C, Clarke K, Shekhar S, Tao CV	Big Spatiotemporal Data Analytics: a research and innovation frontier (Han, Liu, Sui, & Zhou, 2021)	2020	spatiotemporal framework, ML		
10	Wen R, Li S	Spatial Decision Support Systems with Automated Machine Learning: A Review (Wen & Li, 2022)	2023	AutoML, DL	spatially explicit models	Satellite imagery UAV imagery Sensors Surveys Sociodemographic Simulations
11	Song W, Keller JM, Haithcoat TL, Davis CH	Automated geospatial conflation of vector road maps to high-resolution imagery	2009	Normalized Difference Vegetation Index	spatially explicit models linear feature extraction	MODIS, QGIS
12	Wang S, Wang E, Zhong Y, Yun W, Lu H, Cai W	Geospatial Big Data Analytics Engine for Spark (Wang et al., 2017)	2017	ML	FeatureRDD Spark	SuperMap object for Java and Apache Spark

13	Gouriisankarrb huniaa· H, Adimallaanarsi mhaaeditors P	Advances in Geographic Information Science Geospatial Technology for Environmental Hazards Modeling and Management in Asian Countries Ethical Use Of Information Technology In Higher Education			spatially explicit models, mage segmentation model, Semantic segmentation, convolutional neural networks	
14	Zhong Y, Li J, Zhu S	Clustering Geospatial Data for Multiple Reference Points (Zhong, Li, & Zhu, 2019)	2019	ML Clustering	APPROXIMA TION SEARCH ALGORITHM	R
15	Saldana-Perez M, Torres-Ruiz M, Moreno-Ibarra M	Geospatial Modeling of Road Traffic Using a Semi-Supervised Regression Algorithm (Saldana-Perez, Torres-Ruiz, & Moreno-Ibarra, 2019)	2019	support vector machine method	SVM regression, SVR regression	QGIS, Python
16	Jiang W, Zhang L	Geospatial Data to Images: A Deep-Learning Framework for Traffic Forecasting (Arundel et al., 2020)	2019	deep learning	Convolutional Neural Network (CNN) and residual networks	Historical Average (HA) and AutoRegressi ve Integrated Moving Average (ARIMA)
17	Chauhan L	Geospatial AI/ML Applications and Policies: A Global Perspective	2021	DL, ML		
20	Chauhan LP, Shekhar S	GeoAI - Accelerating a virtuous cycle between AI and Geo (Alastal & Shaqfa, 2022),	2021	DL, ML	spatially explicit models, image segmentation model, Semantic segmentation, convolutional neural networks	SAGA
23	Arundel ST, Li W, Wang S	GeoNat v1.0: A dataset for natural feature mapping with artificial	2020	ML	Classification, region-based convolutional neural network	GNIS Database, TerrainAI

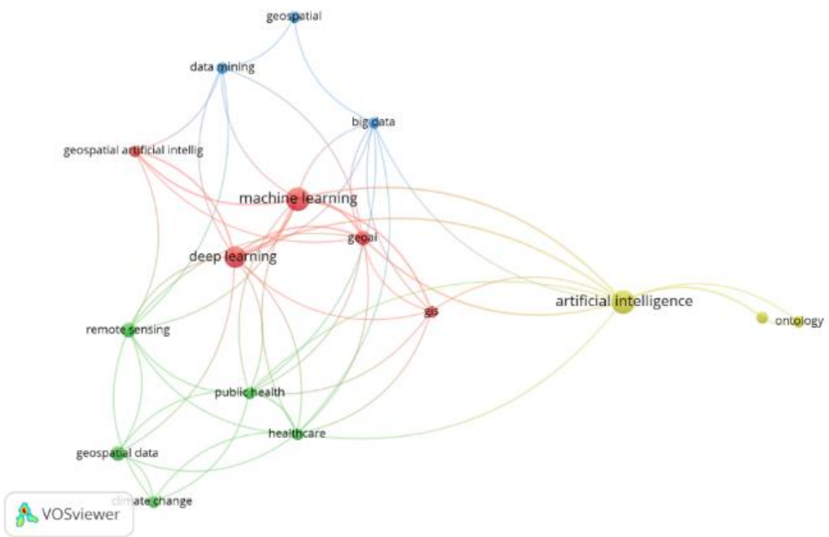
		intelligence and supervised learning [				
24	Mich L	Artificial Intelligence and Machine Learning	2020	ML		
28	Li W, Hsu CY	GeoAI for Large-Scale Image Analysis and Machine Vision: Recent Progress of Artificial Intelligence in Geography (PS Chauhan & Shekhar, 2021)	2022			
29	Cso	Geospatial analysis for Machine Learning in Tactical Decision Support (Xu, 2021)	2022	ML	Genetic Algorithms and Reinforcement Learning	spatial data and satellite imagery
30	Boulos MN, Wilson JP	Geospatial techniques for monitoring and mitigating climate change and its effects on human health	2023	ML	Spatial reasoning	remote sensing data and satellite imagery
31	Alastal AI, Shaqfa AH	GeoAI Technologies and Their Application Areas in Urban Planning and Development: Concepts, Opportunities and Challenges in Smart City (Kuwait, Study Case) (Li, 2021)	2022	ML DL	Classification, Clustering	SAGA, QGIS, Arcgis
34	Cugurullo F	Urban Artificial Intelligence: From Automation to Autonomy in the Smart City	2020	ML, DL	Classification, Regression	Arcgis ESRI, QGIS
35	Abujayyab SK, Karaş IR	Datasets Structuring and Classification Tool: Case Study for Mapping Lulc from Rasat Satellite Images	2019	ML	Classification	Arcgis

36	Döllner J	Geospatial Artificial Intelligence: Potentials of Machine Learning for 3D Point Clouds and Geospatial Digital Twins	2020	ML DL	3D Point clouds	Cesium,3D, CesiumJS
38	Rocha TA, de Almeida DG, Kozhumam AS, da Silva NC, Thomaz EB, de Sousa Queiroz RC, de Andrade L, Staton C, Vissoci JR	Microplanning for designing vaccination campaigns in low-resource settings: A geospatial artificial intelligence-based framework	2021			
39	Alright M, Bitar H, Meccawy M, Mullachery B	Utilizing geospatial intelligence and user modelling to allow for a customized health awareness campaign during the pandemic: The case of COVID-19 in Saudi Arabia	2022	ML	Classification	ESRI ArcGIS
40	Bhatti UA, Yu Z, Yuan L, Zeeshan Z, Nawaz SA, Bhatti M, Mehmood A, Ain QU, Wen L		2020	Geometric algebra	Clifford–Fourier transform (CFT), quaternions (sub-algebra of GA), Clifford SVM and NNs	Python
42	Boulos MN, Peng G, Vopham T	An overview of GeoAI applications in health and healthcare	2019	MLDL	Classification, Clustering	
43	Bordogna G, Fugazza C	Artificial Intelligence for Multisource Geospatial Information	2023	ML DL	CNN, RCCNN, LSTM, and GANs	
45	Li W	GeoAI and Deep Learning (Li, 2021)	2021	ML	Generic ML Models	
46	Drishya Girishbai	Future road map for Geodata towards Geospatial	2018	ML	spatiotemporal data	

		Artificial Intelligence				
48	Nizzoli L, Avvenuti M, Tesconi M, Cresci S	Geo-semantic-parsing: AI-powered geoparsing by traversing semantic knowledge graphs (Nizzoli et al., 2020)	2020	GSP (Geo Semantic Processing)	Regression	
50	Dewandaru A, Supriana SI, Akbar S	Evaluation on geospatial information extraction and retrieval: Mining thematic maps from web source	2015	Geographic Information Retrieval (GIR), ML	the nearest neighbour algorithm, SVM, linear discriminant analysis	QGIS, Python
52	Barrera-Narváez CF, González-Sanabria JS, Cáceres-Castellanos G	Geographic information systems and business intelligence in decision-making in the tourism	2020	ML	Classification Clustering	Python
53	Selvaraj MP, Pradeepa PV	GeoSpatial Data Analysis Using Markov Models	2012	ML	Markov Models	R, GEE

1) Visualization

Furthermore, this research will show how network visualization, overlay visualization, and density visualization with the keyword "GeoAI" can be seen in Figures 1, 2, and 3.



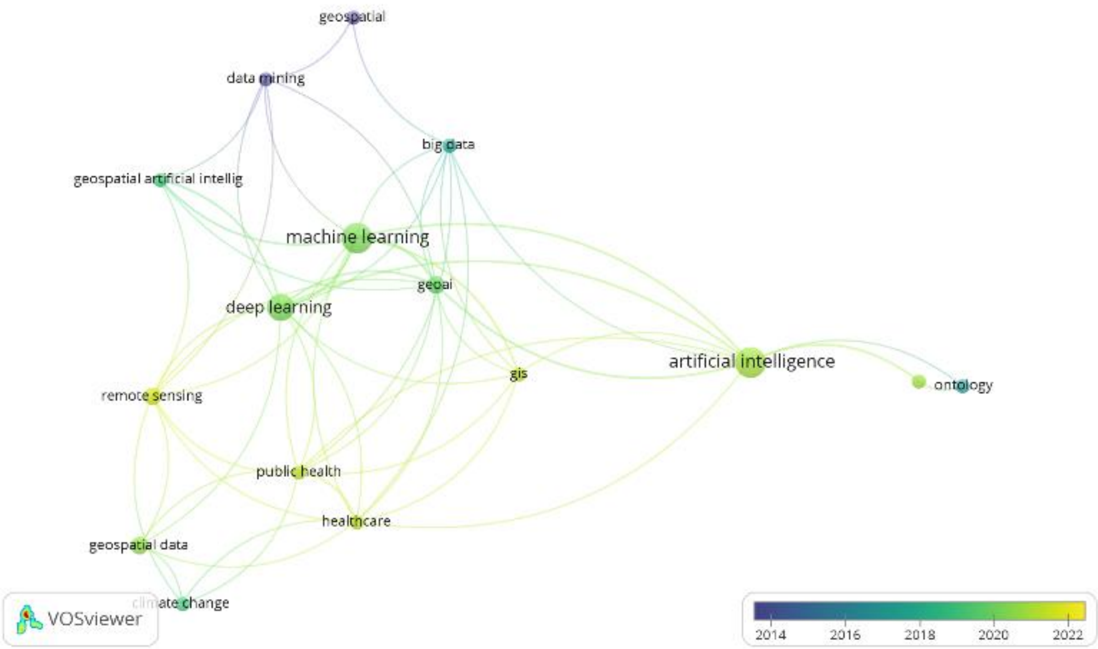
Figures 1 *Network Visualization*

Figure 3 shows the existence of 10 clusters, which are detailed in the table below, with the keyword "Machine Learning" being mentioned the most at 17. The second position which is often mentioned is "Deep Learning" 16 times. However, if you look closely, there are similar keywords, namely GeoAI (14) and Geospatial Artificial Intelligence (21). Other keywords that are closely related to Geospatial and Artificial Intelligence have received many reviews, namely Healthcare, Public Healthcare, Remote Sensing, and Sustainability. More details can be seen in Table 2

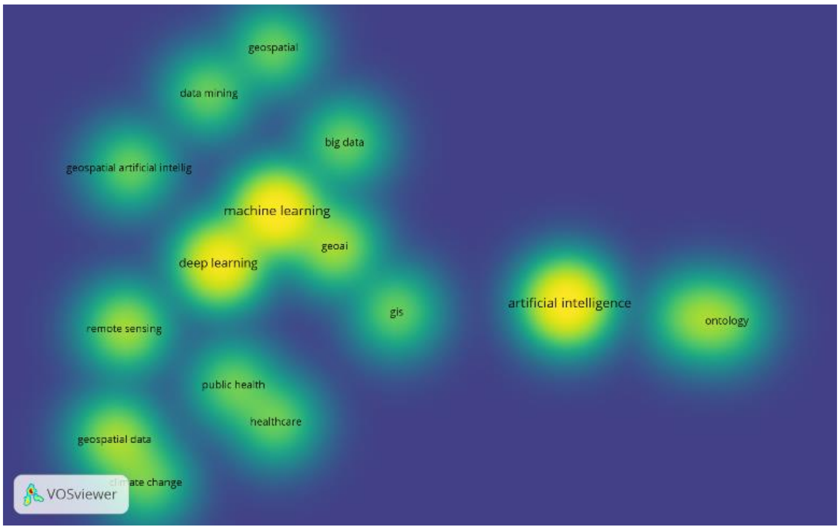
Table 2 Keyword Clustering

Cluster	**Element**
1	*Deep Learning, GeoAI, Geospatial Artificial Intelligence, GIS, Machine Learning*
2	*Climate Change, Geospatial Data, Healthcare, Public Health, Remote Sensing*
3	*Data, Data Mining, Geospatial*
4	*Artificial Intelligence, Ontology, Sustainability*

Table 2 shows what keywords appear in searches via VosViewer. If you look closely, there are several technologies mentioned in relation to GeoAI, namely Machine Learning, Deep Learning, GIS, and Remote Sensing. These three are technologies that are considered important today. It has been proven that in several applications, technology is the basis used in developing artificial intelligence. An example is Machine Learning although several methods are mentioned in the article (classification, clustering, etc.), what often appears is Machine Learning. Also, from the table, several keywords are more related to implementation, such as Healthcare, Public Health, and Sustainability. If you look at the trend, there are lots of data sets used for Sustainability monitoring.



Figures 2. *Overlay Visualization*



Figures 3 *Density Visualization*

Figures 2 and 3 show that there are still many variables that are hot to be raised as research issues. Machine Learning and Deep Learning are still the most discussed topics.

2) Gap Analysis

GeoAI topic according to the author, this topic is still in the development and exploration stage of methods and models from ML and DL, so there is still a gap in the GeoAI topic, but this is one of the hottest variables to discuss, namely the gap between GeoAI and Sustainability and Ontology, there are still visible gaps even though there seems to be a relationship.

Conclusion

There were many inputs for researchers who would like to be involved in the development of new machine-learning methods and techniques in the future. For example, the development of a deep learning framework for traffic forecasting, if further developed, will undoubtedly become the state-of-the-art method for forecasting techniques based on geospatial data and ultimately improve forecast accuracy. Therefore, from this description, GeoAI will expand, and the proposals outlined by the author will hopefully be implemented by researchers in the future.

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