A Review Geospatial Artificial Intelligence (Geo-AI): Implementation of Machine Learning on Urban Planning

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Abstract. Geospatial Artificial Intelligence (Geo-AI) is aninteresting 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, by maximizing the effectiveness of land use spatial data on the area as upstream data and developingGIS-based tourism applications to display the results of analysis and predictions of tourist 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 NVivosoftware 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 ofapplications and models including visualization. By treating issuesin geospatial artificial intelligence, the overall aim of the researchis 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 there were 5 models that were compared and relevant to the geospatial dataset displayed inthe form of a literature review matrix. Visually included in the relevant keywords in the bibliometric analysis. Interdisciplinary results that are developing and are urgently needed by both government and private stakeholders in the development of smartcities 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).

1. INTRODUCTION

GeoAI, which is a field that is constantly evolving and aimsto assist processing and spatial analysis of big data, and can alsobe 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.

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According to Gartner, GeoAI is the use of artificial intelligence(AI) methods, including ML and DL[1], to generate knowledgethrough spatial and image data analysis. The increasing availability of geographic data, the development of AI, and theavailability 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 locationsor position marker. Geospatial data is widely used in many scientific fields and applications, including smart cities, transportation, business, public health, public safety, resilienceto 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[2]. Various disciplines are involved in shaping this interdisciplinary field, including computer science, geography, geographic information systems(GIS), as well as 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 GeoAIand more general AI, 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[3], the overall aim of the research is to improve thequality of life for Indonesia's growing urban population.

2. LITERATURE REVIEW

Previous research was obtained before doing SLR. Alastal andShaofa[4] research about 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 GeoAItools 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 inKuwait, as well as some recommendations. W. Li and C. Y. Hsu [3], research based on various types of imagery or structured data, including satellite and drone imagery, street views, and geo-scientific data, and their application to a variety of image analysis and machine vision tasks. While different applicationstend 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) highaccuracy; (4) sensitivity in detecting subtle changes; (5) noise tolerance. K. Janowicz, et al [6] research on GeoAI for geographic knowledge discovery, explains how changes in dataare driving the rapid growth of GeoAI, and points out future research directions. 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 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.

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3. METHODS

The research method that will be used in this study uses themethod proposed by Moher D et al [8] namely PRISMA Systematic Literature Review (SLR)[4] where the search for therequired article comes from an electronic database obtained using the VOS Viewer and Publish or Perish software. Moher explained an overview of the methodology in the 4 phases/stages used which can be seen in Figure 1.

Figure 1. Research Methods

1. Identification

At this stage identification is carried out from the collection ofarticles that have been obtained whether there are duplications.If there is duplication, one of the articles will be deleted. Fromthis stage, all articles that have been obtained are not duplicated.

2. Screening

At this stage a check is made for the suitability of the content with the title of the article and the Geo-AI topic, whether it is related to the topic being discussed or not. at this stage, the number of articles available is still entirely based on the keywords, titles and contents that have been determined. In thisstage the initial coding is given in each literature by naming theyear and the author.

3. Eligibility

At this stage a check is made on the feasibility of the existing paper producing a paper that is more supportive of the researchbeing conducted.

4. Included

At this stage, checking the feasibility of existing papers is carried out to produce the most supportive paper from the research conducted.

In the flow of these stages, it is detailed in searching for articleswith a meta-analysis of each article that has been obtained andillustrated with the SLR Prisma Flowchart [9], as shown in Figure 2.

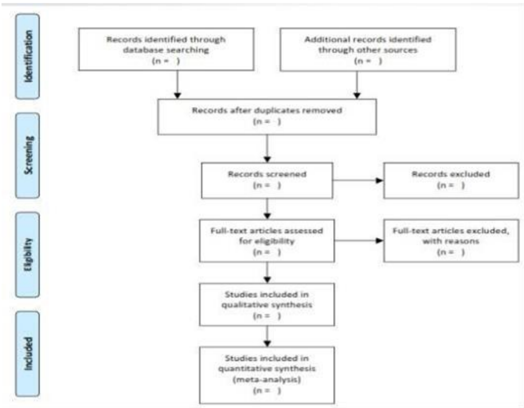


Figure 2. Research Stages

4. RESULTS AND DISCUSSION

4.1 Identifucation

Significant work using SLRs in climate change studies wascarried out by Berrang-Ford[5]. The authors adopted their recommendations for the SLR primarily for outlining the research questions and objectives, selection of data sources and documents, and analysis and presentation of results. The authors conducted a layered literature review to determine the inclusionand exclusion of findings that were more relevant to study publications using the Scopus research engine by publication nolater than June 26, 2023, with a time span 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, Geospatial AI. The second stage involved exclusion to further refine the results in the previous literature review[5]. Exceptions include improvements to the field of study, namely urban planning andtourism, 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 andurban topics that are covered under the topic of Geo AI in a verygeneral scope and that touch on tourism and urban planning issues but not specifically in Indonesia. Further exceptions are warranted when the author deems the scope too broad..

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 not always 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 further determine exclusion from thelist. Finally, there are 38 ingredients selected.

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 Models4.Tools

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[6],. Meanwhile, GeoAI provides learning algorithms and techniques such as machine learning, deep learning[7], and knowledge transfer, to develop effective and innovative solutions for geospatial and earth problems[8], [1], [9]. 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 analysisissues can be classified into the following categories: identifying spatial patterns [10], exploring spatial factors[9],, spatial simulation [19], [20], and geographic decision making[16]. Despite differences in scope and focus, geo- computation and GeoAI have significantly advanced methods of geospatial analysis and mapping in recent years and have thepotential 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[11], cloud computing [22]) (such as Google Earth Engine)[12], graph knowledge[13]), GeoAI has become a driving force in advancing geospatial data utilization[14]. 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 increasinglyimportant 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, leading to 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 [25], spatial heterogeneity to describe variations in geospatial data across space [17], [26], [27], spatial singularity and spatial anomalies to detect observations unusual and rare data, and to measure similarity and complexity[28] 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 [19], the incorporation of these geospatial features is still limited. 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 (eg 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 [29]. with SLR contains a review ofGeoAI 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 Geo-AI,and Tools. This case review categorizes applications in findinggaps 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 literature review

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

Table 1. Matrix Framework

No	Authors	Title	Year	Method	Models	Tools
1	Berrang-Ford L,Pearce T,Ford JD	Systematic review approaches for climate change adaptation research[5]	2015			

2	Vopham T,Hart JE,Laden F,Chiang YY	Emerging trends in geospatial artificial intelligence (geoAI): Potential applications for environmental epidemilogy[15]	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 forgeographic knowledge discovery and beyond[6]	2020	DL, ML	spatially explicit models, question answering, and social sensing,	EarthCube, ESRI
4	Liu P,Biljecki F	A review of spatially-explicit GeoAIapplications inUrban Geography[9]	2022	DL, ML	Deep neural networks and spatially-explicit GeoAI	ESRI
5	Pierdicca R,Paolanti M	GeoAI: a review of artificial intelligence approaches for the interpretation ofcomplex geomatics data[1]	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

6	Song Y,Kalacska M,Gašparović M,Yao J,Najibi N	Advances in geocomputation and geospatial artificial intelligence (GeoAI) for mapping[11]	2023			
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[16]	2021	DL, ML	dynamic geospatial knowledge graph	
8	Fischer MM	Spatial Analysis and GeoComputation : Selected Essays[17]	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[18]	2020	spatiotemporal framework,ML		
10	Wen R,Li S	Spatial Decision Support Systems with Automated Machine Learning: A Review [19]	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[20]	2009	Normalized Difference Vegetation Index	spatially explicit models linear feature extraction	MODIS, QGIS
12	Wang S,Wang E,Zhong Y,Yun W,Lu	Geospatial Big Data Analytics Engine for Spark [21]	2017	ML	Feature RDD Spark	SuperMap iObject for Java and Apache Spark

	H,Cai W					
13	Gouriisankarrbhuniaa· H,Adimallaa narsimhaaeditors 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 [22]			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[23]	2019	ML Clustering	APPROXIMATION SEARCH ALGORITHM	R
15	Saldana-Perez M,Torres-Ruiz M,Moreno-Ibarra M	Geospatial Modeling of Road Traffic Using a Semi-Supervised Regression Algorithm[24]	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[25]	2019	deep-learning	Convolutional Neural Network (CNN) and residual networks	Historical Average (HA) and AutoRegressive Integrated Moving Average (ARIMA)
17	Chauhan L	Geospatial AI/ML Applications and Policies: A Global Perspective[26]	2021	DL,ML		

20	Chauhan LP,Shekhar S	GeoAI - Accelerating a virtuous cycle between AI and Geo[3], [27]	2021	DL,ML	spatially explicit models, image segmentation model, Semantic segmentation, convolutional neural networks	SAGA
21	Li D,Shao Z,Zhang R	Advances of geo-spatial intelligence at LIESMARS[27]	2020			
22	Ang KL,Seng JK,Ngharamike E,Ijemaru GK	Emerging Technologies for Smart Cities' Transportation: Geo-Information, Data Analytics and Machine Learning Approaches [24]	2022			
23	Arundel ST,Li W,Wang S	GeoNat v1.0: A dataset for natural feature mapping with artificial intelligence and supervised learning [[25]	2020	ML	Classification, region-based convolutional neural network	GNIS Database, Terrain AI
24	Mich L	Artificial Intelligence and Machine Learning [26]	2020	ML		
25	Majid GM,Mufreni A,Fitria V	Artificial Intelligence (AI) Penetration and Sustainable Tourism in Indonesia: A Review and Synthesis[27]	2020	ML, NLP		
26	Chauhan L	Geospatial AI/ML Applications and Policies: A Global Perspective[28]				

27	Geospatial G	United Nations Committee of Experts on Global Geospatial Information Management COMMITTEE OF EXPERTS ON Future trends in geospatial information management: the five to ten year vision SECOND EDITION [31]				
28	Li W,Hsu CY	GeoAI for Large-Scale Image Analysis and Machine Vision: Recent Progress of Artificial Intelligence in Geography[8]	2022			
29	Cso	Geospatial analysis for Machine Learning in Tactical Decision Support [10]	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[32]	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) [7]	2022	ML DL	Classification, Clustering	SAGA, QGIS, Arcgis

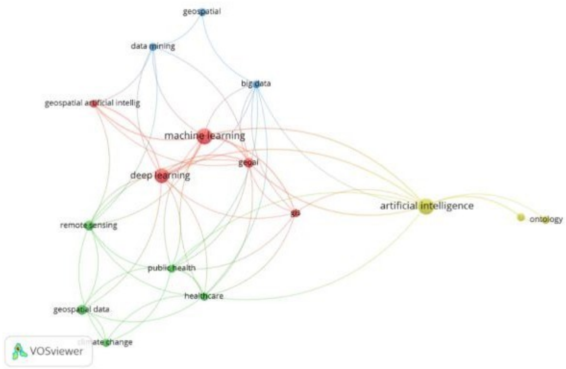
32	Li S,Dragicevic S,Castro FA,Sester M,Winter S,Coltekin A,Pettit C,Jiang B,Haworth J,Stein A,Cheng T	Geospatial big data handling theory and methods: A review and research challenges [29]	2016			
33	Zhu W	Artificial Intelligence and Urban Governance: Risk Conflict and Strategy Choice[30]	2021			
34	Cugurullo F	Urban Artificial Intelligence: From Automation to Autonomy in the Smart City [35]	2020	ML, DL	Classification, Regression	Arcgis ESRI, QGIS
35	Abujayyab SK,Karaş IR	[31]ATASETS 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[32]	2020	ML DL	3D Point clouds	Cesium ,3D, Cesium JS
38	Rocha TA,de Almeida DG,Kozhumam AS,da Silva NC,Thomaz EB,de Sousa Queiroz RC,de Andrade	Microplanning for designing vaccination campaigns in low-resource settings: A geospatial artificial intelligence-based framework[33]	2021			

	L,Staton C,Vissoci JR					
39	Alrige M,Bitar H,Meccawy M,Mullachery B	Utilizing geospatial intelligence and user modeling to allow for a customized health awareness campaign during the pandemic: The case of COVID-19 in Saudi Arabia [34]	2022	ML	Classfication	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
41	Gonzales-Inca C,Calle M,Croghan D,Haghighi AT,Marttila H,Silander J,Alho P	Geospatial Artificial Intelligence (GeoAI) in the Integrated Hydrological and Fluvial Systems Modeling: Review of Current Applications and Trends [35]	2022			
42	Boulos MN,Peng G,Vopham T	An overview of GeoAI applications in health and healthcare[36]	2019	MLDL	Classification, Clustering	
43	Bordogna G,Fugazza C	Artificial Intelligence for Multisource Geospatial Information [36]	2023	ML DL	CNN, RCCNN, LSTM, and GANs	

44	Gao S	Geospatial Artificial Intelligence (GeoAI) [37]	2021			
45	Li W	GeoAI and Deep Learning [7]	2021	ML	Genveric ML Models	
46	Drishya Girishbai	Future road map for Geodata towards Geospatial Artificial Intelligence [38]	2018	ML	spatio-temporal data	
48	Nizzoli L,Avvenuti M,Tesconi M,Cresci S	Geo-semantic-parsing: AI-powered geoparsing by traversing semantic knowledge graphs [13]	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 [39]	2015	Geographic Information Retrieval (GIR), ML	nearest neighbor 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 [40]	2020	ML	Classification Clustering	Python
53	Selvaraj MP,Pradeepa PV	GeoSpatial Data Analysis Using Markov Models [41]	2012	ML	Markov Models	R,GEE

Visualization

Furthermore, this research will show how network visualization, overlay visualization, and density visualization with the keyword "GeoAI" can be seen in figure 3, 4, and 5.



Figures 3. Network Visualization

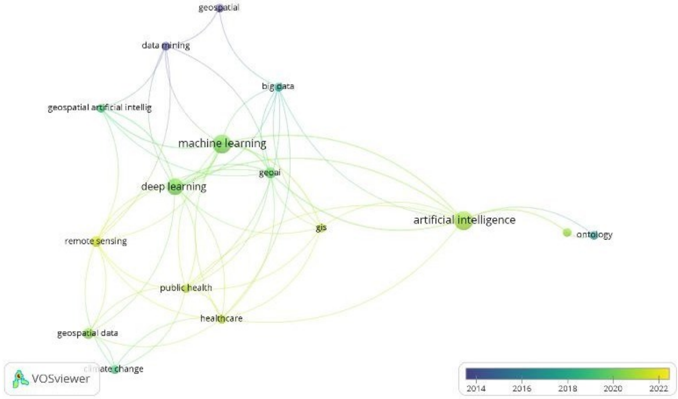
Figure 3 shows the existence of 10 clusters which are detailed in the table below, with the keyword "Machine Learning" beingmentioned the most at 17. The second position which is often mentioned is "Deep Learning" 16 times. However, if you look closely, there are similar keywords, namely GeoAI (14) and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

Table 2. Keyword Clustering

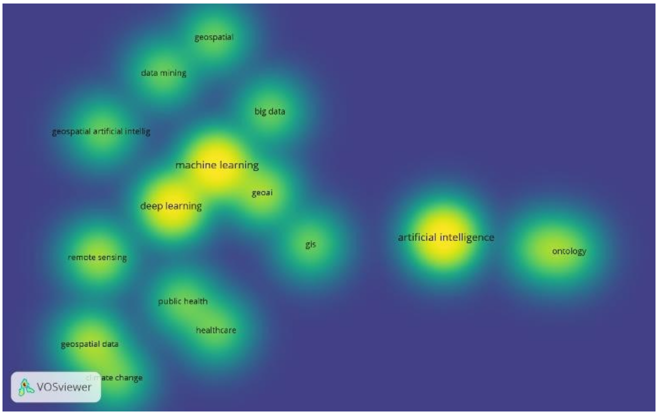
Cluster	Element
1	***Deep Learning, GeoAI, Geospatial Artificial Intelligence, GIS, Machine Learning***
2	***Climate Change, Geospatial Data, Healthcare, Public Health, Remote Snsing***
3	***Bigdata, Data Mining, Geospatial***
4	***Artificial Intelligence, Ontology, Sustainability***

Table 2 shows what keywords appear in searches viaVosViewer. 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 is used in although several methods are mentioned inthe article (classification, clustering, etc.) but what often appears is Machine Learning. Also from the table, it can be seen that several keywords are more related to GeoAIimplementation, such as Healthcare, Public Health, and Sustainability. If you look at the trend, there are lots of data setsused for Sustainability monitoring.



Figures 4. Overlay Visualization



Figures 5. Density Visualization

Figures 4 and 5 show that there are still many variables that arehot to be raised as research issues. Machine Learning and DeepLearning are still the most discussed topics.

Gap Analysis

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

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