

GeoAI Technologies and Their Application Areas in Urban Planning and Development: Concepts, Opportunities and Challenges in Smart City (Kuwait, Study Case)

Abdelkhalek I. Alastal, Ashraf Hassan Shaqfa

Geography and GIS Department, Arts College, Islamic University of Gaza, Gaza, Palestine
Email: abdelkhalek.alastal@gmail.com, Ashaqfa@iugaza.edu.ps

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Abstract

Artificial intelligence has significantly altered many job workflows, hence expanding earlier notions of limitations, outcomes, size, and prices. GeoAI is a multidisciplinary field that encompasses computer science, engineering, statistics, and spatial science. Because this subject focuses on real-world issues, it has a significant impact on society and the economy. A broad context incorporating fundamental questions of theory, epistemology, and the scientific method is used to bring artificial intelligence (AI) and geography together. This connection has the potential to have far-reaching implications for the geographic study. GeoAI, or the combination of geography with artificial intelligence, offers unique solutions to a variety of smart city issues. This paper provides 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. Also shown are key areas of applications and models in GeoAI, likewise challenges to adopt GeoAI methods and technology as well as benefits. This article also included a case study on the use of GeoAI in Kuwait, as well as a number of recommendations.

Keywords

Smart City, Geospatial Artificial Intelligence, Machine Learning, Deep Learning, Convolutional Neural Network, Geographic Information Systems

1. Introduction

Geospatial artificial intelligence, often known as GeoAI, has recently gotten a lot

of interest. GeoAI, which is an evolving field that aims to help organize how we think about and approach processing and analyzing spatial big data, can be described as an emerging scientific discipline that combines innovations in spatial science, AI methods such as ML, and DL, data mining, and high-performance computing. According to Gartner, GeoAI is the use of AI methods, including ML and DL, to produce knowledge through the analysis of spatial data and imagery [1]. The increased availability of geospatial data, the advancements of AI, and the availability of massive computing power has resulted in the mounting relevance and potential of GeoAI. The concept was placed in the broader framework of AI-intra relationships as a sub-discipline of AI that uses ML to extract knowledge from spatial data [2].

Needless to say, GeoAI systems, these days, play an important part by developing conventional technologies AI and innovating new techniques to address unique challenges imposed by The nature of huge, complex, various, and increasing geospatial data, which is considered geo-referenced data with location markers.

As we can also observe that geospatial data are vast spreading in many science and application domains such as smart cities, transportation, business, public health, public safety, resilience to natural disasters, climate change, etc. By processing these issues, the overall goal is to improve the quality of life for the growing urban population worldwide. Various disciplines are involved in shaping these interdisciplinary fields, including computer science, geography, Geographic Information Science (GIS), as well as urban studies.

The purpose of this article is to provide an overview of key concepts surrounding the emerging field of GeoAI, Clarifying the difference between GeoAI and Standard AI, Integrating AI with GIS, Presenting the most important GeoAI tools and software.

Additionally, discussing main steps to successful geospatial data analysis and Key areas of applications and models, displaying the main Challenges and advantages which facing adopting GeoAI methods and technologies, Also, Provide a successful practical example of using GeoAI in Kuwait as a case study.

2. Concept of GeoAI

First and foremost, given the nature of the topic and due to the overlap of artificial intelligence with many different scientific disciplines and fields, we need clarification some basic terms of artificial intelligence and Geospatial, as the following:

Definitions [3] [4]

1) Artificial Intelligence: Artificial Intelligence: The study and design of machines or computational methods that can perform tasks that normally require human intelligence, such as reasoning, learning and foresight that enables it to function appropriately in its environment.

2) Machine Learning: A subfield in AI that relies on statistical methods or

numerical optimization techniques to derive models from data without explicitly programming every model parameter or computing step.

3) Deep Learning: A special type of machine learning where artificial neural networks, and algorithms inspired by the human brain, learn the patterns and prediction rules from large amounts of data.

4) Convolutional Neural Network: CNNs are a class of deep learning algorithms that use convolution rather than general matrix multiplication in at least one of their neural network layers.

5) GeoAI: is an emerging scientific discipline that combines innovations in spatial science, AI/ML methods (e.g., deep learning), data mining, and high-performance computing to extract knowledge from spatial big data.

6) Geospatial: A collective term for data and associated technologies having a geographic or locational component, often relative to Earth.

For each of the previous terms, there are a number of definitions, and the definition for each term was chosen to be suitable for this study. AI and other previous are popular terms in this era. And knowing what it is and the difference between them is more crucial than ever. Although these terms might be closely related, there are differences between them. Please see **Figure 1** to visualize it.

T. Vopham *et al.* [6] defined GeoAI as “an emerging scientific discipline that combines innovations in spatial science, artificial intelligence methods in machine learning (e.g., deep learning), data mining, and high-performance computing to extract knowledge from spatial big data” and [7] illustrates that “the molding together of artificial intelligence (AI) and the geographic information systems (GIS) dimension creates GeoAI”.

Thus, GeoAI is where geospatial technology, imagery and artificial intelligence converge. As well, Geospatial AI can also be called a new form of machine learning that is based on a geographic component. **Figure 2** illustrates the concept of GeoAI.

AI refers to machines that make sense of the world, automating processes that create scalable insights from big data [8].

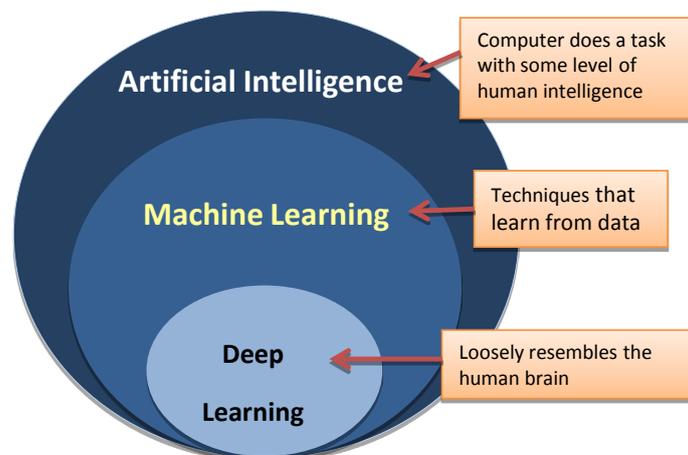


Figure 1. Relation inside AI. Source: [5].

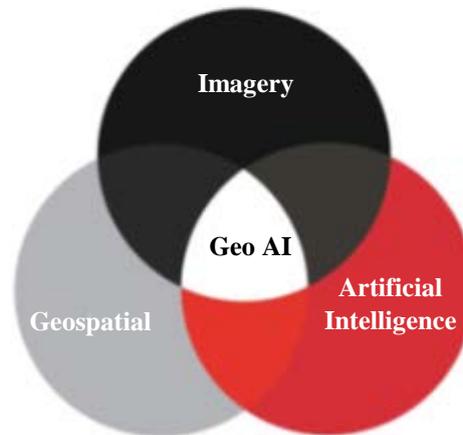


Figure 2. GeoAI concept.

Machine learning is a subset of AI that focuses on computers acquiring knowledge to iteratively extract information and learn from patterns in raw data [8] [9]. DL is considered a subgroup type of machine learning that draws inspiration from brain function, representing a flexible and powerful way to enable computers to learn from experience and understand the world as a nested hierarchy of concepts, where the computer is able to learn complicated concepts by building them from simpler concepts [8]. Deep learning has been applied to natural language processing, computer vision, and autonomous driving [8] [10].

While Data mining refers to techniques to discover new and interesting patterns from large datasets such as identifying frequent item sets in online transaction records [6]. Many techniques for data mining were developed as part of machine learning [11]. GeoAI is an emerging science that utilizes advances in high-performance computing to apply technologies in AI, such as ML, DL and DM to extract meaningful information from Geospatial big data. Likewise, GeoAI is a specialized field within spatial science because particular spatial technologies, including GIS, must be used to process and analyze spatial data, as it is specifically focused on applying AI technologies to analyze spatial big data for developing decisions and action.

3. Differences between GeoAI and Standard AI

To begin with, Geospatial data and spatiotemporal data for its analysis require a very different way of reasoning than solving other classic AI problems. To be analyzed properly, vector data that indicates the connectedness of objects, where requires different kinds of algorithms like CNN. GeoAI also remains an emerging discipline and needs innovation in addressing various topics such as higher dimensional data, real-time applications and hyperspectral. **Table 1** presents the main important differences between GeoAI and classic AI.

Each of these aspects of geospatial data makes GeoAI a highly interdisciplinary field linking different disciplines like computer science, engineering, statistics, geography and urban planning.

Table 1. A brief list of reasons why GeoAI tools and applications are different from those in other non-geospatial industrial applications.

Elements	Description
Data type	Geospatial data deals with the physical location, proximity of people and assets in both space and time, making it dynamic as well.
Data volume	The volume of geospatial data is usually very high as it is one of the data intensive application areas where data are extremely large, complex, rapidly growing and often include real-time elements. which captured by sensors, devices and satellites, often dating back decades
Higher dimensional data	Whereas the classical geometry-based analyses use low-dimensional spaces, the Geospatial field use of high-dimensional data is increasing. When combined with real world data, both structured and unstructured geospatial data becomes more high-dimensional which adds to the complexity of AI techniques necessary to solve a given problem.
Preprocessing for AI	Geospatial data requires greater preprocessing than standard AI models. As most standard AI tools are not geared to understand the concepts of geospatial-connectivity, spatial proximity, terrain, etc.
Real-time applications	Many GeoAI applications such autonomous vehicle, predictive routing, and asset tracking require real-time processing and immediate results for decision making using the complex and structurally different data than text or images analyzed by standard AI models.
Hyperspectral	Unlike simple images, geospatial data can cover multiple spectral frequencies beyond the visible-light frequencies. When the ultraviolet and infra-red bands are included in the data collected, it is called multi-spectral, and when all available frequency bands are included, it is called hyperspectral. Analyzing hyperspectral data requires different techniques and domain expertise as even mineral constituents of objects detected can be identified.

Source: [4].

4. Integrating AI with GIS

It's clear that combining two technologies, AI and GIS proved to be highly promising to the more beneficial and efficient world. AI made a major footstep that has been arising independently in GIS. During the last decade, there is a significant convergence between the fields of GIS and AI. GIS is an admired technology that provides vast data sets and wide scope of applications for AI. Recent Projects were designed to examine and compare different techniques for predictive modeling of Geographic Phenomena distributions.

As well In this regard, AI aims to utilize its techniques to promote intelligent information processing in GIS. Moreover, it gives excellent solutions for modeling, such as real-world applications. AI methods in GIS applications have mainly following goals are:

- Improve selective approaches in spatial patterns.
- Reaching the predictive accuracy and allocating of spatial modeling technique independently and as an integrated model for diverse datasets.
- AI techniques provide insight into critical spatial functions and processes through rule extraction and factor sensitivity tests.

5. GeoAI Tools

With the exponential growth of the usage of the services provided by AI, the analysis of geo data has become more popular. ML has been a core component

of spatial analysis in GIS. Where GeoAI systems has tools to help with every step of the data science workflow including data preparation and exploratory data analysis; training the model; performing Geospatial analysis; and finally, disseminating results using web layers and maps. **Figure 3** summarizes the main components of ML in GIS.

As well, AI includes tools for helping with data preparation for DL workflows and has been enhanced for deploying trained models for feature extraction or classification, providing the ability to deploy DL models at scale by leveraging distributed computing. **Figure 4** and **Figure 5** show the main tasks of deep learning processing of GIS.

6. GIS Software

There are different types of GIS software applications that can help analyze geographical data, which can create, manage, analyze and display data on the map. **Table 2** illustrates the list of most important GIS software available in the market.

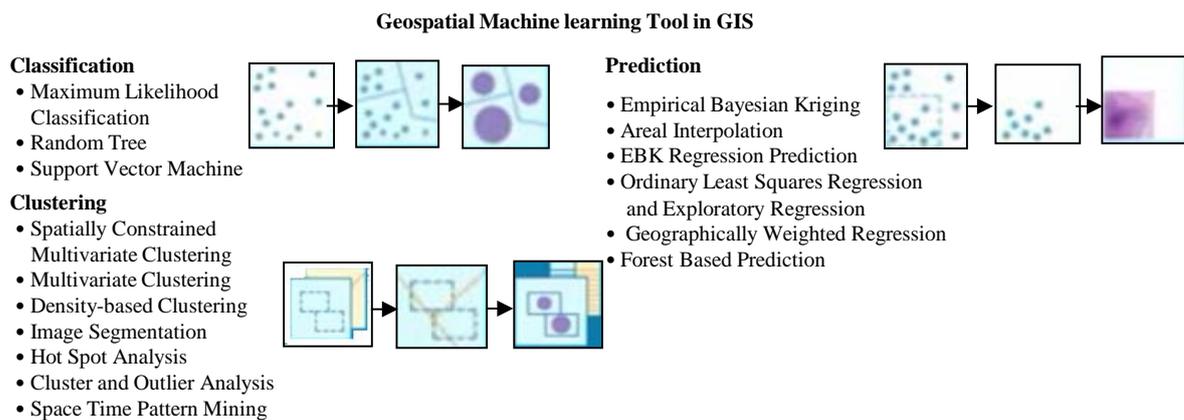


Figure 3. Geospatial machine learning tool in GIS. Source: [12].

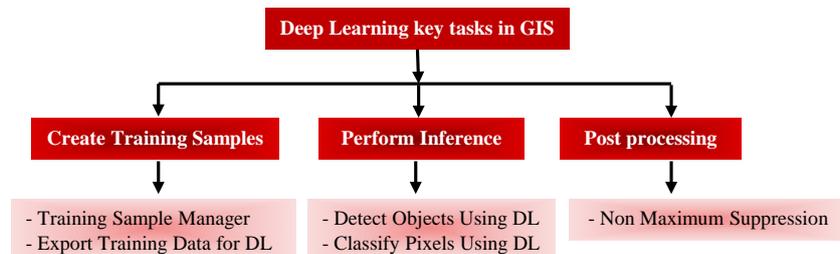
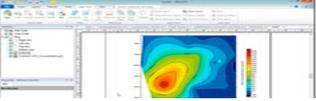
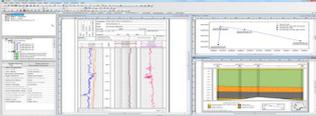
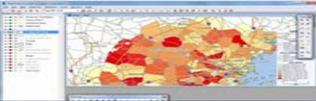
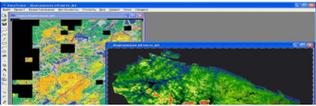
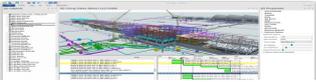


Figure 4. Deep Learning key tasks in GIS.



Figure 5. Deep learning processing in GIS.

Table 2. Commercial and free open source GIS software.

Software	Description
Commercial GIS software	
Surfer	Is a GIS software, which visualizes and creates enhanced maps and models with various options for customization. This geographic information system can re-define maps and models with the finest details.
	
Strater	With such online GIS software, it can achieve insights and clarity by transforming raw data into easy to understand well logs and borehole models. The user will be able to create high quality geotechnical reports that communicate vital information. And can be view and analyze hidden areas and make well-informed decisions.
	
Geosoft Target	The user can create insightful data and great geological models to enhance the decision-making ability. This software will help to get intuitive geological modelling and analysis through multi-disciplinary geoscience.
	
ArcGIS Software	
	The ArcGIS software is a part of Esri Geospatial Cloud, which enables you to connect data and locations using interactive maps. With intuitive analysis tool, location intelligence is achieved accurately.
Maptitude	This GIS software uses geoscientific analysis for creating elegant visualizations of maps, performing business analysis and data integration of corporate revenue. These are necessary for developing commercial solutions based on well researched demographics.
	
Intergraph	This software offers geospatial solutions in the form of business intelligence, aerial digital camera, video analysis solutions and geomeia. This GIS software provides physical information security management through computer aided dispatch.
	
Easy Trace	Easy Trace is an AutoCAD-oriented digitization program. It is a cartographic raster to vector conversion tool for multithreading and editing topologically connected objects. The user can take advantage of automatic object recognition and such utilities for topological structure control and automatic correction.
	
eSpatial	It's a cloud-based mapping software for visualizing, analyzing and uploading several layers of data. The mapping software uses advanced geographic analysis for the purpose.
	
Bentley	Bentley is used to unify disparate 2D/3D data and remove such data as well. This software offers flexible API for creating GIS applications and high quality maps.
	
Open Source & Free GIS Software	
QGIS	Also known as Quantum, GIS is an open source. GIS software used for analyzing and editing geospatial data. This open source platform composes/exports graphical maps and depends on raster/vector layers. You can use QGIS for supporting shapefiles, coverage, personal geo databases and MapInfo.
	

Continued

OpenJump



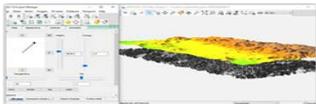
It is an open source GIS mapping software used for editing and attributing data in the software's map display. It is also possible to export data into SVG. You can utilize vector analysis tools for topologic analysis and overlay operations. Further, it helps add coordinate reference system, spatial database analysis and bug fixing through OpenJump platform.

SAGA GIS



System for Automated Geoscientific Analyses (SAGA) is meant primarily for geodata analysis and processing. This open source GIS software has a robust API, programmed within the system designed and object oriented C++ language. It is specifically used for Georeferencing and cartographic projections.

GRASS GIS



Geographic Resources Analysis Support System (GRASS), open source GIS software, is used for geospatial data analysis and management. Graphics, image processing and maps production are other core features of the platform. It is powered by a 3D-raster.

Source: [13].

7. Key Steps to Successful Geospatial Data Analysis

To begin with, it is important to emphasize that spatial analysis will not be effective by just running software, or a model, but must be a workflow and an approach continuous to problem solving in real life. The following are key steps to successful geospatial data analysis [14].

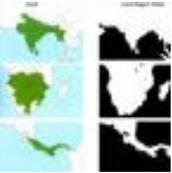
- Defining questions: Formulate hypotheses and geospatial questions.
- Exploring the data: Checking the data quality, completeness, and measurement limitations (scale and resolution) to determine the level of analysis and interpretation that can be supported.
- Analyze and model: Breaking the problem down into solvable components that can be modeled. Quantify and evaluate the geospatial questions.
- Interpreting the results: Evaluating and analyzing the results in the context of the question posed, data limitations, accuracy, and other implications.
- Recur as needed: Geospatial analysis is a continuous and iterative process that often leads to further questions and improvements.
- Display the results: The best information and analysis becomes increasingly valuable when it can be effectively presented and shared with a larger audience.
- Make a decision: Geospatial analysis and GIS are used to support the decision-making process, where a successful spatial analysis process often leads to the understanding necessary to drive decisions and action.

8. Key Areas of Applications and Models in GeoAI

In today's competitive world, progressions in the application of AI to Geospatial data are starting to show promising signs of being able to unblock its true potential. Despite the large-scale projects being specifically geospatial and applied, AI methods are still relatively few. However, there is now a rising awareness that geospatial diversity, in level and pattern of locations, and the role that temporal

change and level have in addressing applications and developing models that help decision-making and research. Thus, GeoAI techniques and systems can deliver sustains the interest of commercial and governmental organizations to push innovation and maintain sustainable development. **Table 3** displays the main fields of applications and models in GeoAI.

Table 3. Main fields of applications and models in GeoAI.

Object Detection	Pixel Classification	Object Classification	Instance Segmentation
<p>Models:</p> <ul style="list-style-type: none"> - Single Shot Detector - Retina Net - Faster RCNN <p>Applications:</p> <ul style="list-style-type: none"> - Detect trees, cars, airplanes, swimming pool, well pads. - Detect encroaching structures. - Moving objects like road cracks/catfish on video - Road signs, and other assets in oriented imagery - Detecting and counting vehicles. - Shipwrecks in Bathymetric data. - Fire hydrants in Oriented imagery.images. 	<p>Models:</p> <ul style="list-style-type: none"> - UNet Classifier - PSPNet Classifier - Deep Lab - Point Rend support for better accuracy <p>Applications:</p> <ul style="list-style-type: none"> - Land Cover Classification. - Pervious/Impervious Mapping. - Building Footprint Extraction. - Cloud detection. - Road detection. - Water meters from oblique 	<p>Model:</p> <ul style="list-style-type: none"> - Feature Classifier. <p>Applications:</p> <ul style="list-style-type: none"> - Damaged building classification. - Clean pools. - Broken/flashed insulators. - Identifying plant species. 	<p>Models:</p> <ul style="list-style-type: none"> - Mask RCNN <p>Applications:</p> <ul style="list-style-type: none"> - Building footprint extraction. - 3D roof reconstruction. - Sinkholes 
Scanned Map Digitization	Image Translation	Point Cloud Classification	Image Captioning
<p>Class:</p> <ul style="list-style-type: none"> - Scanned Map Digitizatizer <p>Applications:</p> <ul style="list-style-type: none"> - Digitizing scanned maps. - Geo referencing Scanned maps. 	<p>Models:</p> <ul style="list-style-type: none"> - Pix2Pix - Cycle GAN - Super Resolution <p>Applications:</p> <ul style="list-style-type: none"> - SAR to Optical imagery. - Imagery to Map generation. - Annotate Imagery. - Increase image resolution. 	<p>Models:</p> <ul style="list-style-type: none"> - Point CNN <p>Applications:</p> <ul style="list-style-type: none"> - Classifying point cloud data (building/ground, etc) - Power line and utility poles extraction. 	<p>Models:</p> <ul style="list-style-type: none"> - Image Captioner <p>Applications:</p> <ul style="list-style-type: none"> - Annotating Images. - Accessibility for Images. 

Continued

Road Extraction	Change Detection	Edge Detection
<p>Models:</p> <ul style="list-style-type: none"> - Multi Task Road Extractor <p>Applications:</p> <ul style="list-style-type: none"> - Extract Road Networks - Routing 	<p>Models:</p> <ul style="list-style-type: none"> - Change Detector (based on STANet) <p>Applications:</p> <ul style="list-style-type: none"> - Identify new building. - Identify new construction. 	<p>Models:</p> <ul style="list-style-type: none"> - BDCN Edge Detector - HED Edge Detector <p>Applications:</p> <ul style="list-style-type: none"> - Residential parcel extraction. - Agricultural farm boundaries. 

Source: [15].

9. Challenges Facing Adopting GeoAI Methods and Technologies

Needless to say, applying successfully GeoAI's methodology and techniques necessitates taking into account the unique obstacles that working with spatial data presents. While GeoAI can be a tool for enhanced growth, efficiency, security, and more, there are still many obstacles that can be summarized as follows:

- **Rising hardware costs:** As result geospatial data keeps growing constantly, there will be an increased necessity for high-performance computing to process it. This will escalate the hardware costs to manage such a system.
- **Ethical violation:** There are issues related to the concerns of violation ethical values with regard to the collection of high-resolution geospatial data.
- **Lack of experts:** There are insufficient experts in the field of GeoAI, as it is an emerging technology. At the same time, it does not only require technology knowledge but one should have analytical and interpretive skills too [16].
- **Data quality:** it is critical to confidence in decision making. As data are more unstructured and collected from a wider array of sources, the quality of data tends to decline. A data quality control process needs to be established to develop quality metrics, evaluate data quality, repair erroneous data, and assess a trade-off between quality assurance costs and gains [17].
- **Data errors:** The source of the data should be understood to minimize the errors caused while using multiple datasets. The properties and limits of the dataset should be understood before analysis to avoid or explain the bias in the interpretation of data [18].
- **Data cleaning:** is a process of eliminating incomplete, inaccurate and redundant data from the input geospatial data source. It should be the first step of any geospatial big data project. Generally, datasets contain a high level of redundan-

cy which should be eliminated to reduce the overall cost of the project [19].

- Life-cycle of geospatial data: Most application scenarios in GeoAI systems require the real-time performance of big geospatial data analytics. There is a need to define the life cycle of the data, the value it can provide and the computing process to make the analytics process real-time, thus, increasing the value of the analysis [19].
- Security and privacy: GeoAI systems and applications require high security and privacy since the data will move over various types of networks. Confidential data and information are also stored in databases. So that the high level of security and privacy of unauthorized access is the bigger issue in smart city applications [20].
- Geospatial data analytics system: Traditional RDBMS are suitable only for structured data and they lack scalability and expandability. Though geospatial (non-relational) databases are used for processing unstructured data, there exist problems with their performances. There is a need to design a system that combines the benefits of both relational and non-relational database systems to ensure flexibility [19] [21].
- Geospatial data visualization: Visualization helps in decision analysis at each and every step of the data analysis. Visualization issues are still part of data warehousing and Online Analytics Processing (OLAP) research. There is a scope for visualization tools for high-dimensional data [19].

10. GeoAI Systems Advantages

The biggest advantages of GeoAI systems are that the massive geospatial datasets collected from the survey, sensing, and social media would provide rich data sources and geospatial context for GeoAI unique advantages that may represent important opportunities, and the most important of which can be reviewed below:

- Increased availability of geospatial data, the advancement of AI and the availability of massive computing power have created momentum for the digital exploitation of geospatial data.
- AI technology presents new opportunities to integrate, exploit, and use geospatial data for geospatially-informed insights and predictions.
- Geospatial data could be leveraged by coupling it with AI technologies to achieve more efficient solutions regarding digital transformation.
- GeoAI digital technologies could be contributed to accelerating the digital economy and maximizing its potential role in addressing both local and global challenges. Further, it can contribute to reduce costs and increasing efficiency and productivity.
- GeoAI technologies can be applied to improve certain steps in the heterogeneous data life cycle through supported by the data system life cycle and thus maximizing the returns on these datasets.
- Key challenges in scaling GeoAI systems to complex data scenarios. Particu-

larly those based on deep learning which needs large collections of labeled training data, model architecture search, etc. where unique opportunities in the geo-domain to overcome them.

- For improving our understanding of geographic data more efficiently is leveraging humans and machines together. The challenges of reliability and robustness must be highlighted by the general difficulty in model interpretability.

11. Case Study: In Kuwait, GeoAI Helps to Better Serve Residents by Automating Map Updates [22] [23]

Creating a deep learning model and training dataset with GIS allows PACI to automate much of its mapping, realizing immediate benefits in time and cost savings as well as improving the data accuracy.

- Key advantages of Kuwait Finder

- GeoAI Machine learning model allows PACI to automatically update Kuwait's base maps with the new streets and buildings, as shown in **Figure 6**.
- Time spent developing and training a deep learning model returned ever more accurate results.
- Time savings and accuracy improvements directly benefit the citizens and residents of Kuwait in getting better data and directions for less cost.

Kuwait Vision 2035 means major infrastructure growth, and with the Kuwait National Development Plan goal to increase infrastructure expenditures by 11 percent, change is already well underway. Construction projects—including the world's longest causeway, a new airport passenger terminal, and a new 500,000-person residential area called Silk City. The country needs to keep up with ever changing landscape. For continuous confidence, Kuwait Finder must capture and reflect this dynamism, with an up-to-the-moment authoritative geospatial rendition of the whole country.

- Transforming to Automation

PACI established its GIS program in 2011, and needed an up-to-date comprehensive base map for the state of Kuwait. To create Kuwait Finder initially back in 2012, The GIS team pulled together data from various ministries, as well as PACI's internal paper maps and AutoCAD files, to capture the current base map. With the objective of updating the construction of new buildings and changes to the city's streets, they studied satellite imagery to extract details for the map. But by the time the crew found the changes and input them back into the Kuwait Finder database, the infrastructure of Kuwait City had changed once again.

- Deep learning for the best solution

PACI utilized ML to extract street data and building footprints from the satellite imagery while using the minimum amount of human input, as shown in **Figure 7**.

Deep learning, a powerful form of ML, involves teaching a computer to detect patterns in large amounts of data and to recognize and extract just the

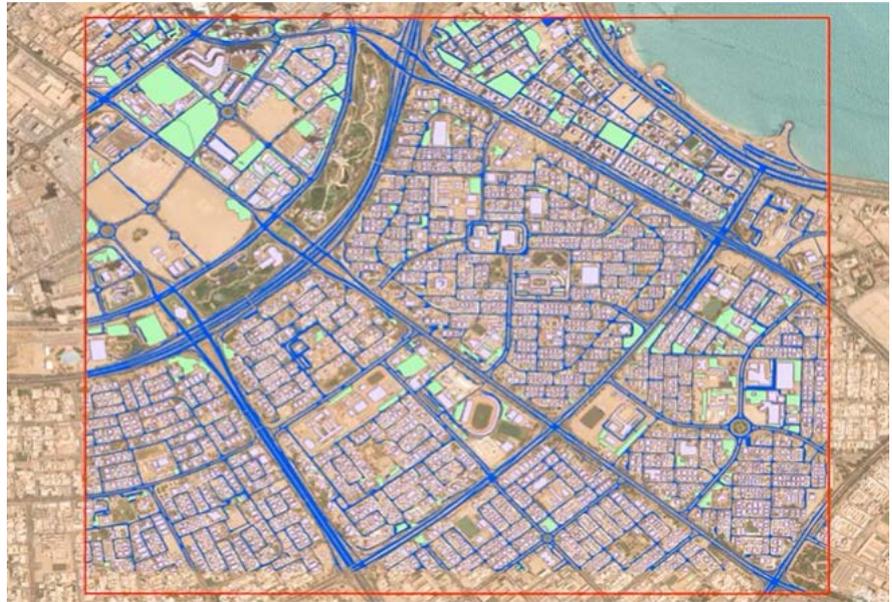


Figure 6. The algorithm recognizes both roads and buildings.



Figure 7. Building footprints digitized manually on the left compared to the deep learning algorithm outputs on the right.

information you want. If done right, the algorithm acts quickly and thoroughly and even finds changes that human intuition would miss. PACI's GIS team needed to teach the computer how to recognize building footprints from satellite data, and also note which ones were new since the last batch of satellite images. PACI's task was a bit more complex as it wanted the computer to tell it about anything new across the entire country. PACI team needed to establish a common geospatial framework that would encompass the existing database. The staff was able to train using 75 square kilometers of data to provide input for the model to scan 3000 square kilometers of satellite imagery.

Once the machine learning model was ready, PACI dedicated time to training and fine tuning the model. Thus, the model and training data set can be used to update the database in about three hours and provide even more accurate maps than before. And this model can continue to be modified and enhanced by PACI into the future, taking into consideration new architecture styles, building types or other new features.

- Reaching the target

The model could now do a task that previously took five humans a year to complete. The time was spent to train the machine to extract features from satellite imagery to the GIS repository with great success.

Now, the organization has the confidence that it can keep the Kuwait base map and Kuwait Finder updated in a timely manner and have it continue to be the authoritative source for information in Kuwait. The time and cost savings from this automation will allow the small team at PACI to keep innovating to stay ahead of the competition. The lessons learned from using deep learning and remotely sensed data will also feed new ideas for PACI staff and will foster more innovation.

12. Recommendations

- Avoid a focus on hardware/IoT (Internet of Things) alone; a focus on Geospatial AI is required.
- Programs for fundamental Geospatial AI research should be encouraged.
- A better long-term vision and strategy for geospatial AI in different areas is required.
- A better balance needs to be found between long-term and short-term needs in terms of basic research, innovation and development.
- More national funding support for Geospatial AI research in academia.
- An enhanced collaboration with companies and technological transfer on Geospatial AI-related development.
- A boost for AI in industry and other economic sectors from the government.
- Establish a national Geospatial AI research agenda for a coordinated large-scale long-term research effort.
- It's important for the investment and creation of Geospatial data infrastructure that makes high quality data sets available to researchers and companies.
- Designing mechanisms to re-skill and up-skill the wider population in the use of AI tools and methods.
- An increase in national research funding for current and potential future GeoAI systems, their novel properties and large-scale reaching impacts, such as safety and health, etc.
- Supporting studies concerning the integration of Geospatial AI into a society that address and propose novel approaches to increase the societal benefit derived from technical advances.
- Focus on human talent to advance research and development in GeoAI. We can attract more talent (e.g. students) from the data science community to work on geospatial problems.

13. Conclusion

As a result of the preceding, we can draw the following conclusion: GeoAI is a new multidisciplinary scientific subject that combines spatial science, artificial

intelligence (especially machine learning and deep learning), data mining, and high-performance computing to extract knowledge from huge data in the geographic domain. GeoAI systems have origins in geographical data science, a growing area that aims to help us structure how we think about and approach processing and analyzing huge data in the spatial domain. The purpose of this paper was to provide an overview of GeoAI technology and discuss the notion of GeoAI and the differences between GeoAI and normal AI, as well as try to explore integrating AI with GIS, likewise GeoAI tools and software, which are essential for efficient geographic data analysis. Also shown were the key areas of applications and models in GeoAI and the challenges and benefits of adopting GeoAI methodologies and technology. This article also included a case study on the use of GeoAI in Kuwait, as well as a list of recommendations. Finally, we can state that GeoAI actively contributes to solving real-world problems in a variety of sectors in a remarkable manner.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] ELISE-European Location Interoperability Solutions for E-Government. <https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/glossary/term/geoai>
- [2] United Nations Committee of Experts on Global Geospatial Information Management. (2015) Future Trends in Geospatial Information Management: the Five to Ten Year Vision. 2nd Edition. https://ggim.un.org/documents/UN-GGIM-Future-trends_Second%20edition.pdf.
- [3] Hu, Y., Li, W., Wright, D., Aydin, O., Wilson, D., Maher, O, and Raad, M. (2019) Artificial Intelligence Approaches. In: Wilson, J.P., Ed., *The Geographic Information Science & Technology Body of Knowledge*, Association of American Geographers, Philadelphia. <https://doi.org/10.22224/gistbok/2019.3.4>
- [4] WGIC Policy Report (2021) Geospatial AI/ML Applications and Policies: A Global Perspective. <https://wgicouncil.org/wp-content/uploads/2021/04/WGIC-Report-2021-01-Geospatial-AI-ML-April-2021.pdf>.
- [5] Esri: Taking a Geographic Approach to Machine Learning. <https://www.slideshare.net/MapsMakeSense/taking-a-geographic-approach-to-machine-learning-esri-ireland-do-one-thing-well-webinar-6>
- [6] Vopham, T., Hart, J.E., Laden, F. and Chiang, Y.Y. (2018) Emerging Trends in Geospatial Artificial Intelligence (geoAI): Potential Applications for Environmental Epidemiology. *Environmental Health*, 17, Article No. 40. <https://doi.org/10.1186/s12940-018-0386-x>
[https://yaoyichi.github.io/papers/VoPham-et-al.-2018-Emerging-trends-in-geospatial-artificial-intelligence-\(geoAI\)-potential-applications-for-environmental-epidemiology.pdf](https://yaoyichi.github.io/papers/VoPham-et-al.-2018-Emerging-trends-in-geospatial-artificial-intelligence-(geoAI)-potential-applications-for-environmental-epidemiology.pdf)
- [7] Boulos, M.N.K., Peng, G. and Vopham, T. (2019) An Overview of GeoAI Applica-

- tions in Health and Healthcare. *International Journal of Health Geographics*, **18**, Article No. 7. <https://doi.org/10.1186/s12942-019-0171-2>
<https://ij-healthgeographics.biomedcentral.com/articles/10.1186/s12942-019-0171-2>
- [8] Cresson, R. (2018) A Framework for Remote Sensing Images Processing Using Deep Learning Techniques. *IEEE Geoscience and Remote Sensing Letters*, **16**, 25-29. <https://doi.org/10.1109/LGRS.2018.2867949>
https://www.researchgate.net/profile/Remi-Cresson/publication/327659573_A_Framework_for_Remote_Sensing_Images_Processing_Using_Deep_Learning_Techniques/inline/jsViewer/5e415f81299bf1cdb91da181?inViewer=1&pdfsDownload=1&origin=publication_detail&previewAsPdf=false
- [9] Zhu, X.X., *et al.* (2017) Deep Learning in Remote Sensing: A Comprehensive Review and List of Resources. *IEEE Geoscience and Remote Sensing Magazine*, **5**, 8-36. <https://doi.org/10.1109/MGRS.2017.2762307>
<https://ieeexplore.ieee.org/document/8113128>
- [10] Li, S., *et al.* (2016) Geospatial Big Data Handling Theory and Methods: A Review and Research Challenges. *ISPRS Journal of Photogrammetry and Remote Sensing*, **115**, 119-133. <https://doi.org/10.1016/j.isprsjprs.2015.10.012>
- [11] Boulos, M. N. K., Peng, G. and Vopham, T. (2019) An Overview of GeoAI Applications in Health and Healthcare. *International Journal of Health Geographics*, **18**, 1-9. <https://doi.org/10.1186/s12942-019-0171-2>
<https://ij-healthgeographics.biomedcentral.com/track/pdf/10.1186/s12942-019-0171-2.pdf>
- [12] IEEE GRSS. GeoAI: Applying Machine Learning and Deep Learning to Geospatial Data. https://www.youtube.com/watch?v=sjhlrrCgKSg&t=2482s&ab_channel=IEEEGRSS
- [13] Riya, B. (2019) 15 Best GIS Software in 2021 for Analyzing Geospatial Data. <https://www.techjockey.com/blog/top-gis-software-for-analysing-geographic-data>
- [14] ESRI (2013) The Language of Spatial Analysis. <https://www.esri.com/content/dam/esrisites/sitecore-archive/Files/Pdfs/library/books/the-language-of-spatial-analysis.pdf>
- [15] European Commission (2020) White Paper on Artificial Intelligence: A European Approach to Excellence and Trust. https://ec.europa.eu/info/sites/default/files/commission-white-paper-artificial-intelligence-feb2020_en.pdf
- [16] Katal, A., Wazid, M. and Goudar, R.H. (2013) Big data: Issues, Challenges, Tools and Good Practices. 2013 *Sixth International Conference on Contemporary Computing (IC3)*, Noida, 8-10 August 2013, 404-409. <https://doi.org/10.1109/IC3.2013.6612229>
https://www.stat.purdue.edu/~doerge/BIOINFORM.D/SPRING16/KatalWazidGoudar_2013.pdf
- [17] Lee, I. (2017) Big Data: Dimensions, Evolution, Impacts, and Challenges. *Business Horizons*, **60**, 293-303. <https://doi.org/10.1016/j.bushor.2017.01.004>
<https://www.sciencedirect.com/science/article/abs/pii/S0007681317300046>
- [18] Boyd, D. and Crawford, K. (2011) Six Provocations for Big Data. In: *A Decade in Internet Time: Symposium on the Dynamics of the Internet and Society*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1926431
- [19] Min, C., Mao, S. and Liu, Y. (2014) Big Data: A Survey. *Mobile Networks and Applications*, **19**, 171-209. <https://doi.org/10.1007/s11036-013-0489-0>

- <http://www2.egr.uh.edu/~zhan2/ECE6111/class/BigDataSurvey2014.pdf>
- [20] Mohbey, K.K. (2017) The Role of Big Data, Cloud Computing and IoT to Make Cities Smarter. *International Journal of Society Systems Science*, 9, 75-88.
<https://doi.org/10.1504/IJSS.2017.083615>
https://www.researchgate.net/profile/K-Mohbey/publication/315883071_The_role_of_big_data_cloud_computing_and_IoT_to_make_cities_smarter/inline/jsViewer/5adf06a40f7e9b285943ad7e?inViewer=1&pdfjsDownload=1&origin=publication_detail&previewAsPdf=false
- [21] Li, H. and Lu, X. (2014) Challenges and Trends of Big Data Analytics. *9th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC)*, Guangzhou, 8-10 November 2014, 566-567.
<https://doi.org/10.1109/3PGCIC.2014.136>
<https://ieeexplore.ieee.org/document/7024647>
- [22] Peters, L. (2020) Deep Learning Helps Kuwait Automate Map Updates to Better Serve Citizens. ESRI.
<https://www.esri.com/about/newsroom/blog/deep-learning-helps-kuwait-automate-map-updates/>
- [23] Esri Events (2021) Geospatial AI: An Overview.
https://www.youtube.com/watch?v=pkL2PU60hTo&list=PLaPDDLTCmy4bl7t6OOCoNX23nrwJldWnW&index=28&ab_channel=EsriEvents

Abbreviations

s.	ACRONYM	DESCRIPTION
1	GeoAI	Geospatial Artificial Intelligence
2	GIS	Geographic Information Science
3	ML	Machine Learning
4	DL	Deep Learning
5	DM	Data Mining
6	PACI	Public Authority for Civil Information
7	CNN	Convolutional Neural Network
8	RDBMS	Relational Data Base Management System
9	OLAP	Online Analytics Processing