Scipioneers Journal of Science and Technology (SJST)

| Website: www.scipioneers.com | Email: research@scipioneers.com

A Study on the Fusion of IoT and AI in Geographic Information Systems (GIS)

1st Amol Gadkari
Dept. Computer Science,
Dr. BAMU, Aurangabad, MH, India.
amolgadkari99@gmail.com

2nd Dr. N. R. Suradkar
Dept. Computer Science,
Shankarlal Khandelwal College, Akola, MH, India.
nitinrs.skc@gmail.com

Abstract:
The Geospatial Intelligence Revolution: A Research Paper on the merging of Geographic Information Systems (GIS), the Internet of Things (IoT) and Artificial Intelligence (AI) is driving a transformative change in our understanding, analysis, and engagement with our spatial surroundings. Historically, GIS functioned as a fixed storage system for spatial information. The surge of IoT sensors has turned it into a vibrant, real-time nervous system of the Earth, producing unmatched amounts of geospatial data. Nonetheless, this torrent of data poses major difficulties in processing, analyzing and extracting insights. AI, especially machine learning (ML) and deep learning (DL), arises as a vital facilitator. This study investigates the interdependent connection among IoT, AI, and GIS analyzing significant application areas including smart cities, precision agriculture, environmental monitoring and disaster management. The study determines that the combination of IoT and AI is fundamentally transforming GIS into a predictive and self-sufficient decision-making system.

Keywords: Geographic Information Systems (GIS), Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning, Geospatial Intelligence.

I. INTRODUCTION

Geographic Information Systems (GIS) have historically been vital instruments for the storage, visualization, and analysis of geographic data to facilitate informed decisions in areas like transportation, agriculture, urban planning, and natural resource management [1], [4]. Historically, GIS platforms depended mainly on static or regularly refreshed datasets, indicating that the spatial representations they provided depicted only previous and already-experienced situations instead of present conditions.

Nonetheless, the swift growth of the Internet of Things (IoT) has fundamentally transformed the essence of geospatial data creation. IoT comprises physical devices that are interconnected and equipped with sensors, which continuously gather and transmit data regarding their environments—including location, movement, and environmental conditions [2], [3]. Billions of IoT sensors integrated into smart devices, vehicles, buildings, and infrastructure now serve as constantly active data sources, facilitating real-time geospatial observation on an unprecedented scale. Processing large volumes of Big Data goes beyond the capabilities of manual spatial analysis and challenges the constraints of conventional GIS systems. Here is where Machine Learning (ML) and Artificial Intelligence (AI) are essential. AI/ML methods facilitate automated detection of features, mining of spatial patterns, predictive analysis, and identification of anomalies from diverse geospatial datasets that are otherwise too extensive and intricate for human understanding [4], [5], [7]. Consequently, GIS transforms from mere static mapping into a dynamic analytical framework that can predict urban mobility, identify environmental hazards instantly, and assist spatially-aware autonomous systems.

This integration transforms GIS from a descriptive and diagnostic instrument—clarifying past occurrences—into a forward-looking geospatial intelligence system that can foresee future spatial events and recommend the best responses [9]. Essentially, the integration of IoT and AI is evolving GIS into a constantly updating, decision-making platform that enables more intelligent, quicker, and context-sensitive operations throughout various industries and governmental systems. This work aims to present the converging GIS–IoT–AI framework, highlight major real-world application domains, examine technological and ethical challenges, recommend future research directions including digital twins and federated learning.

II. LITERATURE REVIEW

Recent research has emphasized the significant effect of combining IoT and AI technologies within GIS-based systems. Batty [1] presented the idea of digital twins as dynamic virtual models of real-world environments, laying the groundwork for sophisticated urban simulations. Azzam et al. [2] highlighted the increasing integration of IoT and GIS within smart cities, detailing architectural frameworks and noting interoperability and security as important issues. Li et al. [3] examined the rapid expansion of IoT data defined by its volume, velocity and variety, emphasizing the need for sophisticated analytics that surpass conventional GIS functionalities. Expanding on this, Li, Goodchild and Wu [4] demonstrated AI-based geospatial analytics, especially deep learning methods which greatly improve the interpretation and automation of spatial data. Craglia et al. [5] bolstered this idea by tackling the governance challenges and policy implications linked to AI in Earth observation systems.

Evidence from Zhang and Zhou [6] showed that real-time sensor networks combined with spatial modeling enhance responsiveness and precision in managing disaster situations. In the field of agriculture, Kamilaris and Prenafeta-Boldú [7] demonstrated the efficacy of deep learning for monitoring crop health and optimizing yield, thus backing precision farming efforts. Zhou et al. [8] broadened these advantages to smart mobility by utilizing advanced spatio-temporal deep learning models that can forecast traffic congestion and enhance transportation efficiency in urban GIS frameworks. In the meantime, Liu et al. [9] emphasized the significance of Edge AI in minimizing latency while handling real-time geospatial data gathered by IoT devices, aiding in more scalable and privacy-respecting implementations. Ultimately, Gadekallu et al. [10] investigated federated learning methods to improve data privacy and adherence to regulations in AI models for smart cities. Collectively, these pieces show that the combination of IoT and AI is transforming GIS into a real-time, predictive, and self-sufficient geospatial intelligence system.

III. METHODOLOGY

The integrated framework is important to bridge the gap between real-world sensing and operational reaction. It facilitates autonomous and optimized decision-making in fields such as smart agriculture, disaster risk reduction, public health surveillance and intelligent transportation. Real-time geo-visualization and spatial analysis allow decision-makers to see where changes occur while AI shows why they happen and what actions should follow.

Additionally, the convergence promotes system interoperability, reduces response time and facilitates resource-efficient planning as societies increasingly depend on interconnected smart technologies, the synergy of IoT, AI and GIS become vital for designing resilient, sustainable and context-aware ecosystems [4][5].

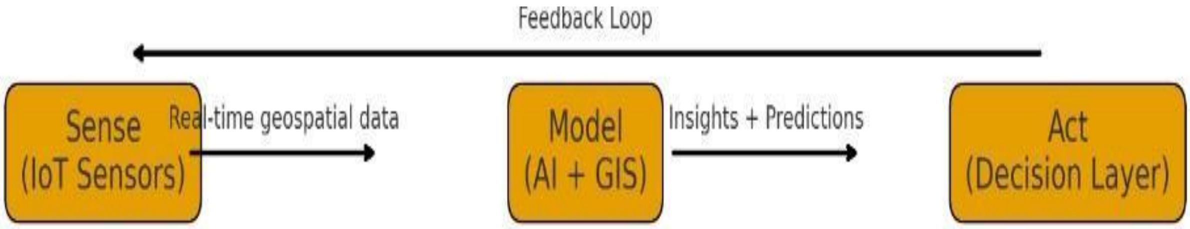

Fig.1. The Convergence Framework

The Integrated Framework of IoT, AI and GIS functions via an ongoing Sense–Model–Act cycle as demonstrated in Fig. 1. In the Sense layer, countless IoT devices act as decentralized sensory nodes gathering real-time geospatial information with spatial and temporal characteristics, including environmental conditions, infrastructure status, and human movement patterns [7][8].

The rapid data flow is subsequently sent to the Model layer, where GIS serves as the spatial data framework while AI and machine learning techniques derive actionable insights through classification, forecasting, anomaly detection and optimization. The acquired insights are moved to the Act layer, where smart systems assist or automate choices, like adaptive traffic control or precision agriculture actions. A feedback loop guarantees that actions produce fresh data, perpetually improving the analytical models and increasing situational awareness [9]. This active process evolves GIS from a fixed mapping instrument into an intelligent, adaptive, and self-sufficient spatial decision-making system.

The process standardizes the movement of data from environmental sensing to AI-driven forecasting and GIS-based representation. It guarantees data integrity, aligns temporal and spatial inputs from various IoT devices and accommodates scalable cloud or edge frameworks. Additionally, the execution process aids stakeholders in grasping their responsibilities and how they interact operationally, guaranteeing that insights generated by AI are not left alone but convert into practical and automated actions in the physical world.

Phase	Core Function	Key Technologies	Output
IoT Data Acquisition	Collect spatial–temporal data	Sensors, Drones	Raw geospatial data
Data Transmission	Stream data securely	5G, MQTT, Cloud	Standardized data hub
AI + GIS Processing	Spatial analytics & predictions	GIS tools, AI models	Actionable intelligence
Decision Layer	Support operations	Dashboards, APIs	Alerts, forecasts
Actuation Layer	Deploy real-world actions	IoT Actuators	Automated execution

Table 1. Implementation Workflow

The convergence of IoT, AI, and GIS is transforming essential sectors by facilitating smart, real-time spatial analysis and automated decision-making. In smart cities, urban IoT networks provide real-time traffic and infrastructure data to AI models in GIS platforms, improving traffic management, lowering emissions, and boosting disaster response predictions [6], [8]. Precision agriculture utilizes IoT soil sensors and drone imagery, assessed by AI within a GIS framework, to generate comprehensive prescription maps for precise irrigation and fertilization, enhancing yield while reducing environmental effects [7]. To monitor the environment, IoT sensors for air and water quality networks, along with satellite image analysis powered by AI, facilitate real-time tracking of pollution, detection of deforestation, and proactive management of ecosystems [4], [5]. In disaster management, the collaboration enhances the whole process: AI-GIS models predict risks by utilizing historical and IoT data, while during incidents, AI quickly evaluates damage from drone and sensor inputs to organize effective, life-saving emergency responses [6]

- *Significant challenges and ethical considerations:*

Privacy threats are significant, especially with location-targeted IoT monitoring, which can reveal confidential user data [3]. Inconsistency of data among various systems complicates integration and analysis, undermining the reliability of insights [2]. Moreover, real-time processing requires significant computational power, which can be expensive and restrict scalability [4], [9]. Algorithmic bias represents a significant issue, as it can unfairly impact marginalized groups and perpetuate social inequalities [5]. Moreover, a significant lack of interdisciplinary knowledge exists, which obstructs the creation and implementation of effective, ethically responsible solutions [10]. Tackling these issues demands strong governance structures and the ethical use of AI to guarantee that technologies are efficient and fair.

IV. CONCLUSION AND FUTURE DIRECTIONS

The combination of IoT, AI, and GIS is reshaping conventional geographic information systems into a sophisticated System of Intelligence, facilitating autonomous and context-sensitive decision-making. This advancement enables spatial data to be collected and visualized, as well as analyzed and utilized in real time, aiding in more intelligent urban planning, resource management, and environmental oversight. Moving ahead, various important paths can further strengthen this ecosystem. Edge AI enables local data processing, greatly minimizing latency and bandwidth requirements while enhancing real-time responsiveness. Explainable AI is essential for building trust and accountability, offering clarity in automated decisions and enabling stakeholders to comprehend, validate, and respond to AI-generated information. The use of Digital Twins—virtual representations of real-world systems—can enhance sophisticated simulation, forecasting, and scenario analysis, leading to better decision-making and timely interventions. Moreover, federated learning offers a valuable method for secure and distributed training of AI models, enabling various organizations or devices to work together in learning from data while safeguarding privacy. Collectively, these innovations will improve the technical abilities of the IoT–AI–GIS ecosystem while also guaranteeing its ethical, efficient, and sustainable implementation in practical applications.

V. REFERENCES

[1] M. Batty, “Digital twins,” *Environment and Planning B: Urban Analytics and City Science*, vol. 45, no. 5, pp. 817–820, 2018.

[2] A. M. Azzam, A. M. Sarji, and M. A. Omar, “Integration of IoT and GIS for smarter cities: A survey,” *IEEE Internet of Things Journal*, vol. 8, no. 12, pp. 10255–10268, Jun. 2021.

[3] S. Li, L. D. Xu, and S. Zhao, “The Internet of Things: A survey,” *Information Systems Frontiers*, vol. 17, no. 2, pp. 243–259, 2015.

[4] Z. Li, W. Goodchild, and X. Wu, “AI-enabled geospatial analytics: Advances and challenges,” *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 185, pp. 236–247, 2022.

[5] A. Craglia et al., “Artificial intelligence and Earth observation: A European perspective,” *International Journal of Geo-Information*, vol. 7, no. 2, pp. 1–21, 2018.

[6] P. Zhang and M. Zhou, "Real-time disaster monitoring using sensor networks and spatial analysis," in *Proc. IEEE International Conference on Big Data*, 2020, pp. 4225–4234.

[7] M. Kamilaris and A. Prenafeta-Boldú, "Deep learning in agriculture: A survey," *Computers and Electronics in Agriculture*, vol. 147, pp. 70–90, Apr. 2018.

[8] Q. Zhou, R. S. McFeeters, and R. Griffin, "Smart city traffic prediction using spatio-temporal deep learning," *IEEE Access*, vol. 9, pp. 34566–34578, 2021.

[9] Y. Liu et al., "Edge AI for real-time geospatial intelligence," *IEEE Network*, vol. 35, no. 6, pp. 72–79, 2021.

[10] T. R. Gadekallu et al., "Federated learning for IoT-enabled smart cities: Recent advances, challenges, and future directions," *Sustainable Cities and Society*, vol. 75, pp. 103–146, 2021.

[11] A. Boutayeb, I. Lahsen-Cherif, and A. El Khadimi, "A comprehensive GeoAI review: Progress, challenges and outlooks," arXiv preprint arXiv:2412.11643, Dec. 2024.

[12] S. E. Bibri, "The synergistic interplay of artificial intelligence and digital twins: Context, challenges and future directions," *Sustainable Cities and Society*, vol. 92, p. 104528, 2024.

[13] A. A. Alnaser, M. Maxi, and H. Elmousalami, "AI-Powered Digital Twins and Internet of Things for Smart Cities and Sustainable Building Environment," *Applied Sciences*, vol. 14, no. 24, art. no. 12056, Dec. 2024. MDPI+1

[14] Y. Hu, "Reflections on advances and limitations in GeoAI research," *Annals of GIS*, 2024 (preprint / working paper).

[15] R. Marasinghe, "Towards Responsible Urban Geospatial AI: Insights From Ethics, Governance and Data-Driven Urban Systems," *GeoJournal*, 2024.

[16] Q. Weng et al., "How will AI transform urban observing, sensing, imaging, and design?," *npj Urban Sustainability*, 2024. Nature+1

[17] B. Jiang, "Bridging space, mind, and computational urban science: Spatio-temporal and graph neural models for dynamic geospatial data," *Urban Computing Journal*, 2025.

[18] D. Yu, "Lifecycle management of urban renewal enabled by IoT and data-driven geospatial analytics," *Urban Studies & Renewal*, 2025.

[19] K. Ambedkar and P. Sahan Kumar, "Data Science for Geographic Information Systems," *International Journal of Creative Research Thoughts (IJCRT)*, vol. 13, no. 5, May 2025.

[20] S. Mazzetto, "A Review of Urban Digital Twins Integration, Challenges, and Future Directions in Smart City Development," *Sustainability*, vol. 16, no. 19, art. no. 8337, 2024.