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TITLE: Artificial Intelligence in Geoinformatics Domain Working Group (GeoAI DWG)

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# Introduction

Artificial Intelligence (AI) is the capability of a functional unit to perform functions that are generally associated with human intelligence, such as reasoning and learning [1]. AI has a long tradition in addressing spatial problems and in investigating spatial domains, e.g., in robotics, or planning and scheduling. For example, k-nearest neighbor queries (a kind of Machine Learning algorithm) or Egenhofer’s nine-intersection model (a spatial reasoning approach) originate in AI and have been integrated with most geographic information systems (GIS) software. AI has been considered in Geoinformatics as an active topic of geo-spatial knowledge discovery [2, 3, 4, 5, 6], such as vehicle trajectory prediction, indoor navigation, historical map digitizing, gazetteer conflation, geographic feature extraction, geo-ontologies, and place understanding. However, AI now provides more powerful and groundbreaking capabilities for geospatial research and development. Recent Deep Learning (DL) neural networks are disrupting traditional AI technologies and bring new requirements and usage models to current systems and applications. Deep learning has inevitably emerged in geoinformatics to the forefront of new generation of geospatial data analytics. GIS software and platforms are also applying DL algorithms (e.g., CNN [7], RNN [8], LSTM [9]) and frameworks (e.g., TensorFlow [10], Chainer [11], Caffe [12], Torch [13], MXNet [14]) to their data processing pipelines for better understanding the world around us. For example, AI-assisted volunteered geographic information (such as OpenStreetMap data) accelerates the build of Spatial Data Infrastructures (SDI) from satellite imagery by using DL methods. Autonomous vehicles gather, manage, and analyze massive geospatial data from a combination of Global Positioning System (GPS), cameras, and other traffic sensors and require little or no human interaction based on rapid success of DL techniques. Although recent AI for the geospatial data focuses on object extraction (such as roads and buildings) from remote sensing images, it is obvious that AI has tremendous potential to benefit a wide range of geospatial applications, including ‘digital twins’ (i.e., a digital replica of physical assets, processes, people, places, systems and devices). For example, autonomous transportation, sustainable smart city planning/implementation, augmented building and energy management, self-optimized manufacturing, predicting epidemic outbreak, and so on. Incorporating geospatial information with AI brings a powerful new dimension to understanding, predicting, and optimizing the real world and improve the quality of our daily life.

As the explosion of AI occurs across business and society, roles and boundaries of AI systems are changing from automated intelligence to assisted, augmented, and autonomous intelligence. From the industry perspective of human-machine interaction ranging from situations [15], AI has replaced (assisted) many of the repetitive and standardized tasks done by humans in hardwired and specific situations. The next stage of augmented intelligence puts humans and machines to work together for a task situation, i.e., to learn from each other and share the decision process. The final stage of autonomous intelligence enables machines to fully make decisions and adapt task situations without human involvement. The report of World Economic Forum [16] addresses a significant impact and opportunity of AI for the Earth. It states that the most important consideration in the development of AI, regardless of the AI stage, is to ensure sustainable benefits for humanity, which include being both “human-friendly” and “Earth-friendly”. It means that AI should promise the trustworthy and safe technology to the Earth as well as human well-beings. With all the enormous potential, AI also poses unintended consequences of performance, security, control, ethical, economic, and societal risks. The DARPA Explainable AI (XAI) program aims to create a suite of machine learning techniques that produce “glass box” models that are accountable to human reasoning with maintaining high performance levels [17]. XAI is important to keep human users in the loop, or to retain their trust in the AI system. The current DL algorithms with little transparency limit the machine ability to explain its rationale, characterize its strengths and weaknesses, and interact with human users. For the safety, explainability, transparency, and validity of AI applications in dealing with spatial information, a collaborative effort among knowledge processing and representation, reasoning, planning and optimization, traditional machine learning, and deep learning is highly required. Furthermore, international standards will ensure wide-spread interoperability and security benefits among the various disciplines that work with AI to lead to the ethical and responsible use of AI technologies in geospatial applications.

This Domain Working Group (DWG) charter defines a role for OGC activities within Geospatial Artificial Intelligence (GeoAI) communities to provide an open forum for the discussion and presentation of interoperability requirements, use cases, pilots, and implementations of OGC standards in this domain. This Charter is to be presented to the OGC’s Technical and Planning committees for consideration.

## Working Group

Operation of an OGC Domain Working Group follows the policies and procedures of the [Technical Committee](http://portal.opengeospatial.org/files/?artifact_id=23325). The following definitions from the Technical Policies and Procedures apply to this DWG Charter template.

Definition of a Domain Working Group: A group (organizationally, a subgroup of the TC) of individuals composed of members of the TC and invited guests, with the specific intent of solving some particular interoperability problem or problems in a particular technology domain for recommendation to the Technical Committee.

Functions of a Domain Working Group:

* Provide a forum for discussion and documentation of interoperability requirements for a given information or user community;
* Provide a forum to discuss and recommend document actions related to Interoperability Program Reports;
* Develop Change Requests Proposals (CRPs) for existing OGC Standards;
* Develop engineering reports with the intent seeking approval by the TC for release of these documents as OGC White Papers, [Discussion Papers](#_Discussion_Papers) or [Best Practices Papers](#_Best_Practices_Documents);
* Informational presentations and discussions about the market use of adopted OGC Standards;
* Have a formal approved charter that defines the DWGs Scope of Work and estimated timeline for completion of the work;
* have all-member voting policies (unless otherwise stated); and
* Have missions and goals defined by the TC.

A DWG does not work on RFC submissions, candidate standards, or revisions to existing OGC Standards. However, a DWG can develop change requests as document interoperability requirements that can then be submitted as work items to a SWG.

A DWG may determine that they wish to have public collaboration, such as in teleconference, email discussions, or a public twiki. In this case, the DWG shall make a motion to the TC to approve public participation in the DWG. Voting in DWGs is by simple majority of OGC Members present at the WG meeting, not just Voting TC Members, with the caveat that no OGC Member organization may cast more than one vote in a WG vote.

# Purpose of Working Group

The GeoAI DWG is chartered to identify use cases and applications related to AI in geospatial domains with its reliance on IoT (e.g., healthcare, smart energy), robots (e.g., manufacturing, self-driving vehicles), or ‘digital twins’ (e.g., smart building and cities). This DWG will provide an open forum for broad discussion and presentation of use cases with the purpose of bringing geoscientists, computer scientists, engineers, entrepreneurs, and decision makers from academia, industry, and government to develop, share, and research the latest trends, successes, challenges, and opportunities in the field of AI with geospatial data. The working group will aim to investigate feasibility and interoperability of OGC standards in incorporating geospatial information with AI and describe gaps and issues which can lead to new geospatial standardization to advance trustworthy and accountability for this domain community. Furthermore, existing OGC Web Services need to be carefully examined for changes that may need to be made in the context of AI-empowered applications. As some AI methods are already included in OGC standards, it is expected that AI methods will also impact many OGC standards in the future. For example, routing services have not yet been built according to human-centered AI, despite some suggestions to extend OpenLS.

# Problem Statement

Recent significant impact of AI is leveraging not the improvement of only machine learning algorithms such as deep learning and reinforcement learning, but also the combination of the Internet of Things (IoT), big data, cloud computing, open-source software, GPU acceleration, and robotics, as well as algorithms. These technologies cooperatively contribute toward realizing high-level human-like perception, cognition, and action by permeating AI into everyday lives. In the geospatial industry, the next-generation of GIS software is expected to be deeply tied with AI technology to make machines/devices cognize the real world and decide on their plan of action by themselves. The global Geospatial Analytics AI Market is expected to grow at a CAGR of 23% by 2023 [18]. Data-driven machine learning algorithms and techniques that automate prediction, classification, and clustering of data has been playing a role in rapid advances of geospatial analysis. For example, DL techniques with high-resolution satellite imagery are applied to classify the type of physical infrastructures like buildings, roads, and rails in a humanitarian mapping workflows [19]. The combination of AI technologies and geoinformatics provide essential advantages for exposure modeling in environmental epidemiology [20]. In particular, the role of geospatial artificial intelligence (GeoAI) becomes crucial for the automation of a cyber-physical system that improves our quality of daily life. For example, autonomous vehicles use geographic location information in integrating data from multiple sensors like cameras, radar sensors, lidar sensors, and ultrasonic sensors for their driving decisions. Autonomous robots will replace humans in disaster areas where humans cannot access. However, there are still several bottlenecks regarding adopting AI technologies, especially deep learning, for human-level intelligence of geospatial analysis and fully autonomous systems.

The risks mentioned above of performance, security, control, ethics, economy, and society make companies and costumers hesitate to trust and adopt AI technologies [16]. The operation within black boxes and with little transparency of how AI works is a challenging the convincing of people to accept the prediction or decision making of AI. The use of traditional aspects of cognitive science, statistical approaches, and metadata would be helpful for building explainability into AI. Also, a lack of data and skilled people lead to model bias from biased training data and misuse of AI. If a training set is prepared for only a specific case and the user cannot understand factors driving model predictions, a decision-maker may face a critical risk of false positive or negative errors. In deep end-to-end learning, the creation of training sets by distilling big data sets is more important than the traditional machine learning approach, which is based on feature engineering by human analysts. Therefore, the role of skilled data professionals such as data scientists and data engineers “in the loop” for ML are essential to mitigate unintended biases and wider performance risks. However, managing massive volumes of data is a challenge in itself. Recent DL algorithms cannot demonstrate their ability to create value out of data without having high-performance computing and distributed data processing infrastructures. However, there is a lack of AI-optimized management for geospatial data, which comprises a significant portion of big data. GeoAI platforms should consider translational models to enable interdisciplinary models to develop new algorithms. As shown in Figure 1, the most marked change of DL approaches is compositionality of constituents to assemble deep stacks of learning components. These models can be assembled in different ways to create a variety of AI-empowered applications and systems customized to individual stakeholder’s needs and supporting innovation. This situation is likely to lead to the importance of the interoperability of data and models between AI-related geospatial technologies for more seamless interaction. Moreover, many stakeholders are still struggling to identify business use cases that can offer considerable benefits. Best practice and uses case across domains, industries, and social organizations will give thought to why and when AI is useful. Finally, ethical and responsible use of AI should be considered to ensure safety, ethics, and privacy is important in the development of AI. “Safety is a prerequisite for sustainable technology. The development of technology poses risks to social trust. How to increase social trust and let the development of technology follow ethical requirements, especially, is an urgent problem to be solved to ensure that privacy will not be violated. To this end, there is a need for developing sound policies, laws, and standards and for cooperation within the international community [21].” In a nutshell, the following benefits should be followed in the development of AI technology.

* Optimize: model performance and decision making;
* Retain: control and safety;
* Maintain: trust and ethics; and
* Comply: Accountability and regulation.



Figure 1. Deep learning model

As AI-related products and services are expanding, there is an issue with the lack of standards supporting many aspects of AI workflows. Foundational standards provide the guidance of industrial innovation and measurements to evaluate the benefits of AI products and services in the international market. Recently, international standardization organizations like IEEE, ITU, ISO, and IEC have started AI-related standards activities.

* IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous System (April 2016).
* ITU has worked on the development of AI standards since 2016:
	+ ITU-T Y.AI4SC, Artificial Intelligence and IoT; and
	+ ITU-T Y.qos-ml, Requirements of machine learning based QoS assurance.
* ISO/IEC JTC 1/SC 42: Artificial Intelligence (April 2018):
	+ Serve as the focus and proponent for JTC1’s standardization program on Artificial Intelligence; and
	+ Provide guidance to JTC1, IEC, and ISO committees developing Artificial Intelligence applications.

OGC Testbed-14 contains a Machine Learning (ML), Deep Learning & Artificial Intelligence task to evaluate how to best support AI and publish inputs to and outputs from Machine Learning and Artificial Intelligence using OGC Web Services [22]. OGC Web Services can be used potentially as a pivotal role to support Machine Learning, Deep Learning, and Artificial Intelligence systems.

The resulting complexity and opportunity in the market place around the field of GeoAI is driving an increased need for standardization to foster the use of AI in geoinformatics. It is time to create a forum to present this domain in the form of an OGC DWG. This DWG is seeking a holistic understanding to derive best practices for integrating ML, DL, and AI tools and principles into OGC Web Service contexts and will play a role to communicate with outside standards organizations.

# Charter

The GeoAI DWG is being established to address the applicability and gaps in the OGC standards baseline with regards to geospatial data in AI applications. Although this group will not be the platform for creating new standards, it will be the platform to discuss and understand any issues, concerns, or barriers to interoperability for the geospatial AI community.

## Charter Members.

Membership of the group will be open to any OGC member at any time, in accordance with the OGC Policies and Procedures. The initial membership of the GeoAI DWG will consist of the following members and individuals with extensive education and experience in GeoAI issues, namely:

Kyoung-Sook Kim Artificial Intelligence Research Center, AIST

Tien-Yin Chou GIS Research Center, Feng Chia University

Zach Wade Real Factors

Michael Rosen Azimetry, Inc.

## Key Activities.

The GeoAI DWG will pursue the following key activities.

1. Collect and analyze AI-related applications and use cases in the geospatial community.
2. Discuss and identify primary GeoAI use cases and applications that would benefit from OGC standards.
3. Identify geospatial requirements in different AI applications for inclusion in existing or new OGC standards.
4. Identify other practice areas in the OGC that support or could be influenced by AI technologies.
5. Identify GeoAI-related use cases and workflows for Interoperability Experiments or Testbeds.
6. Provide guidance and best practices for managing, processing and sharing geospatial data for easily adapting to AI algorithms, tools, or applications.
7. Determine OGC goals and organizational issues that impact GeoAI datasets, technologies, and markets.
8. Promote a robust and traceable GeoAI by defining the quality or metadata elements where reliability/conformance testing results can be stored as well as lineage information for the algorithms.

## Business Case

Artificial Intelligence is expected to play a crucial role in a number of fields from the simplest of appliances to automobiles and will revolutionize our existing technologies in a new industrial age. Advanced machine learning techniques, i.e., Deep Learning, reorient and transform geographic information systems (GIS) and other business operations. GeoAI is important for various participants such as geospatial professionals, local/national authorities, and industries to quickly and easily provide better geospatial insights, assess the impact of potential risks to an event, and improve quality of life in various domains: smart city, environmental management, smart transportation, disaster management, secure environment, etc. GeoAI could be of great benefit to driving the service innovation enabled by the Internet of Things (IoT). Still there are many challenges including interoperability, portability, scalability, safety, explainability, transparency, and validity in this domain. A variety of GeoAI applications will increase the complexity in data exchange and thus create a significant need for recommendations on best practices and the creation of applicable standards. With the support of OGC in the creation and maintenance of relevant standards, the GeoAI domain will benefit by:

* Minimized development and implementation cost for a new GeoAI technique;
* Accelerated deployment of GeoAI applications in the commercial marketplace;
* Enablement of horizontal and vertical integration/composition of GeoAI systems;
* Increased safety around computational approaches and algorithmic techniques that empower the insights provided by AI engines by providing standards; and
* The substantial and sustainable benefit of routine in daily life to reduce risks and downsides.

# Organizational Approach and Scope of Work

## GeoAI DWG Business Goals

The GeoAI DWG will need to establish a set of business goals that frame the basis for determining the nature and type of recommendations made to OGC based on the above-mentioned business issues. Examples of the types of discussion for framing goals include:

* Focus on ML, DL, and AI issues and problems that result in net gain for the community;
* Minimize incompatible technical distinctions between different AI application domains that utilize geospatial data, as this can lead to artificial barriers that limit the potential of all segments of the information community to come together and fully prosper;
* Lower the cost of deploying AI technology in any application domain through the use of standards to increase operational efficiency;
* Maximize the interoperability and usability of geospatial (training) data for various AI tasks such as recognition, prediction, recommendation, planning, optimization, inference, etc.;
* Improve the robustness and traceability in the uses of AI technologies with geospatial data and services; and
* Define the supporting infrastructure for the community to achieve these goals.

## GeoAI DWG: Mission and Role

The GeoAI DWG will concern itself with technology and technology policy issues, focusing on geospatial information and technology interests as related to the AI application domain and the means by which those issues are appropriately factored into the OGC standards development process.

1. The **mission** of the GeoAI DWG is to document the use cases of AI applications that use geospatial data as well as identify opportunities of AI technology in geoinformatics in order to discuss the adoption of existing best practices and standards and/or recommend the creation of new standards to support the successful use of geospatial AI technology.
2. The **role** of the GeoAI DWG is to serve as a forum for the discussion of AI-related topics brought to the DWG from OGC members as well as the larger AI community in order to determine the need for a standards working group (SWG) to further the creation of new standards required to facilitate the growth of geospatial AI technology and to present, refine, and focus interoperability-related issues to the Technical Committee.

## Activities planned for GeoAI DWG

The GeoAI DWG will undertake a range of activities to support the mission of the group and of the broader OGC community. Specific membership objectives include active participation in the DWG as a stakeholder in presenting to the Technical Committee on status and recommendations on how OGC should best participate in the growth of geospatial AI technology.

Specific activities to be undertaken by the GeoAI DWG include:

1. Regular presentations and discussions during Technical Committee meetings;
2. Provide a use case template and criteria to compare use cases;
3. Identify standardization opportunities/requirements based on use cases and application requirements
4. Communicate the requirements of geospatial data and services from the AI community to the OGC;
5. Communicate the geospatial expertise in the OGC, such as existing applicable standards, to the AI community; and
6. Outreach to and organization of OGC members as well as external organizations to contribute to the DWG.

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