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Geospatial AI/ML Applications and Policies: A Global Perspective

World Geospatial Industry Council

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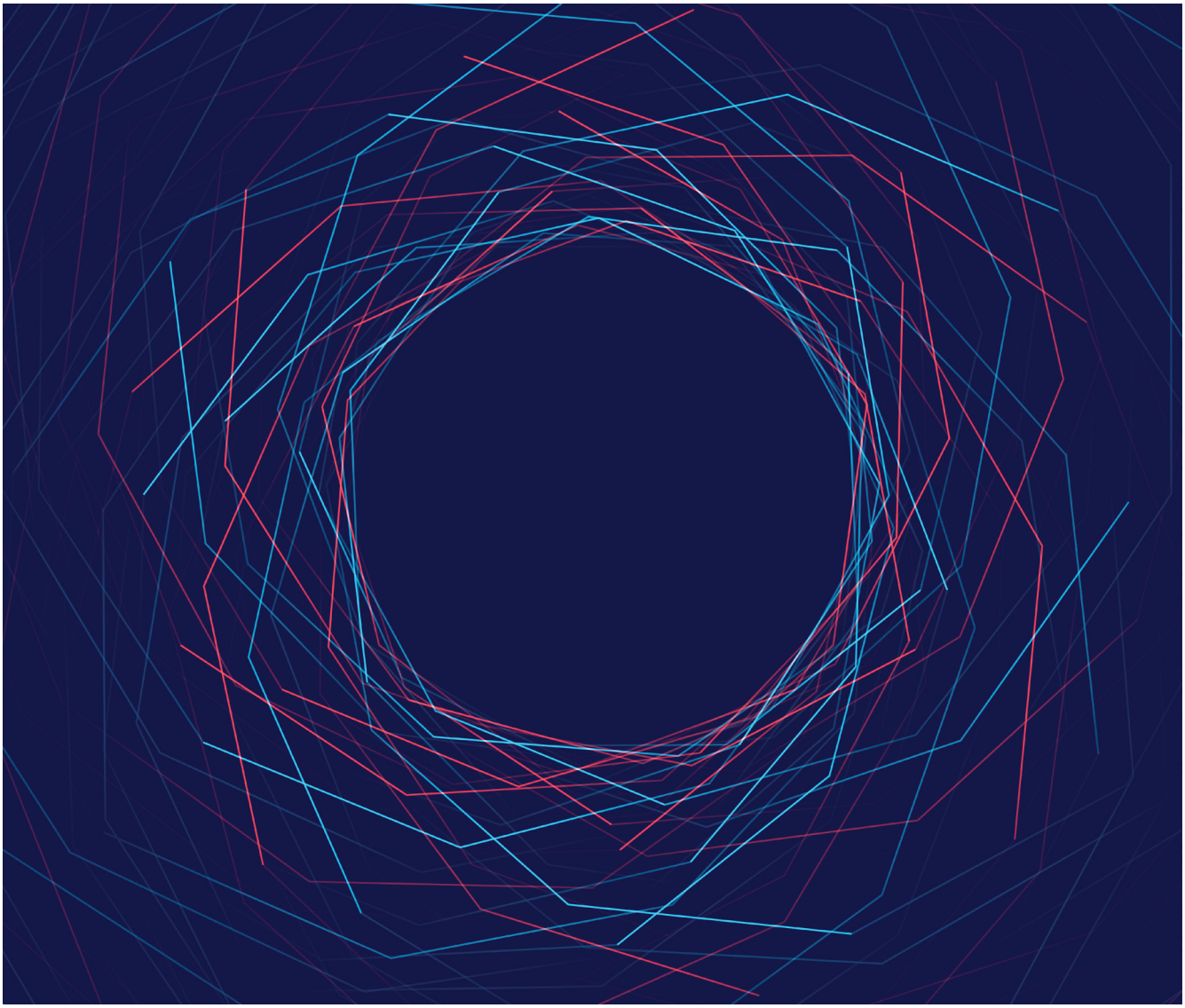

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Executive Summary

I. Introduction

Artificial Intelligence (AI) is becoming pervasive in the systems and solutions we interact with every day and everywhere. We are witnessing sustained increases in the amount of investment and interest from both the public and private sectors. In fact, a US House of Representatives Subcommittee in 2018 described the potential of AI using the following phrase, "AI has the potential to disrupt every sector of society in both anticipated and unanticipated ways".[1] Most recently, the US government has mandated ethically and responsibly developed AI technology in government sourcing and increased funding and coordination of AI initiatives.[2]

AI has the potential to disrupt every sector of society in both anticipated and unanticipated ways – US Congress.

Countries around the globe are making efforts to ensure they are well prepared for taking advantage of the AI revolution. Nation States understand that riding this AI wave underprepared will potentially hurt their prospects and cause upheavals in the lives of their

1 Rise of the Machines: AI and Its Growing Impact on U.S. Policy https://www.hsdl.org/?abstract&did=816362

2 https://hai.stanford.edu/policy/policy-resources/summary-ai-provisions-national-defense-authorization-act-2021

citizens. At the same time, multiple incidents have occurred to caution governments about AI being a double-edged sword. While this has led to a phenomenon of many nations announcing strategies on AI, often declaring their intent to regulate AI and its applications by capping potential harms.

The obvious challenges are related to data privacy related to personal and community/governmental information, intellectual property control and protection, trustworthiness of AI derived insights, socio-economic equality etc. Confronted with this fast-paced AI/ML revolution, public authorities are still trying to understand and define their role in policymaking and regulation in this new domain. This study by the World Geospatial Industry Council (WGIC) will inform both governments and industry players about the use of AI on geographic or location (called geospatial) data, and identify key issues and policy principles.

II. GeoAI – Observations and Trends

Proximity, location and time are critical for explaining most phenomena we observe and experiences we have. This makes the analysis of geospatial data unique. To date, the AI research community has not focused on the requirements presented when analyzing geospatial data (e.g. vector data). Even with specialized geospatial programs at universities there is a lack of AI expertise in geospatial professionals in the workforce. Most geospatial companies therefore train their talent in-house.

Based on the state of AI algorithms, most geospatial AI/ML (GeoAI)[3] use-cases over the next two years are likely to fall into the category of descriptive analysis, meaning that the AI models can identify the objects they are looking for, and perform statistical analysis on such observations. The next phase in the medium term of three to five years is expected to be more of a predictive phase, where the algorithms will be capable of evaluating contextual data (e.g. human geography, mobility, transactions, social media and sensor data), allowing systems to predict or forecast what to expect. The longer term (five years and beyond) will likely be about prescriptive technologies that recommend specific solutions. This sequence is analogous to the Level 1, 2 and 3 of autonomous driving, of the total 5 levels. Current use-cases include, object detection (i.e. monitoring of buildings, farms, roads, infrastructure and assets), high-definition maps, Light Detection and Ranging (LIDAR) based monitoring and point cloud data analysis (i.e. data depicting 3-dimensional space as opposed to 2-dimensional drawings). Overall, these are the use-cases that industry professionals have forecasted, but totally unexpected use-cases may also emerge e.g. Apple has already started putting LIDAR sensors in its devices and others will follow suit. This will create huge amounts of LIDAR data generated by the users of these devices, and it is expected people will use AI to analyze this data. Considering the human ingenuity, right now it's hard to speculate which new AI based use-cases will become fashionable when almost everyone is carrying a LIDAR sensor. For example, augmented reality interactions may just become commonplace like video calls of today.

3 "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." Source: https://ehjournal.biomedcentral.com/articles/10.1186/s12940-018-0386-x

At the same time, the Earth observation (EO) market is rapidly changing with increasing resolutions (spatial, temporal and spectral) and cadence while the costs are falling. Companies in this segment are already calling themselves "AI first" organizations because they are prioritizing AI by increasing the use of deep learning techniques and crowdsourcing to analyze geospatial data. They aim to simplify the analyses required and straightaway answer geospatial content-based queries e.g. how many active construction sites are there in a city, or how many private swimming pools are there in homes, etc. While automation is helping the EO market grow, the limiting factor is the pace of ground truth verification.

AI experts interviewed for this report believe that advances in quantum computing, edge computing, unsupervised learning, hyperspectral data analysis and knowledge guided machine learning will bring in the next set of breakthroughs for GeoAI in the coming decade. Many suggested that more open data and better market-driven sharing mechanisms for proprietary data will promote innovation and fast growth in the geospatial industry. Additionally, difficulty explaining AI's outputs was raised as a concern by most respondents, as it is important to have accountability for actions taken or decisions made at each level of the processing chain.

III. AI Policy Landscape

We started with a cursory review of the laws and policies on AI governance in six jurisdictions where most WGIC members and experts interviewed hail from, namely— Australia, the European Union, India, South Korea, the United Kingdom and the United States of America. In the second phase, we expanded our review to include Brazil, China, the Middle East and Singapore, to ensure more global representation. We analyzed policy papers, laws, regulatory proposals, and soft law in these countries, to understand the legal approaches to AI governance around the globe.

Following are the main observations from the Policy Landscape research:

i. Most countries have not enacted laws on AI governance. South Korea is the only nation which has enacted a sector agnostic law on development of AI and promotion of investment and innovation. This is the Intelligent Robots Development and Distribution Promotion Act, 2008.
ii. The US Congress has included a section for AI law in its defense spending bill that allocates $6 billion for AI research and national level coordination of AI initiatives. It mandates ethical and transparent development of AI systems sourced by the government to ensure accountability.
iii. Australia, the US and the UAE have enacted sector/issue specific AI legislation, largely in the domain of autonomous vehicles, facial recognition technologies and healthcare.
iv. As data is the fuel for the AI economy, we looked at the data protection laws and WGIC's detailed study of privacy laws around the globe[4]. Most countries examined have enacted data protection laws. However, India and the USA do not have a com-

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prehensive federal data protection law but are considering it. Further, some countries examined for the purpose of this paper have frameworks for geospatial information regulation and use.

v. In terms of active consideration of privacy laws, jurisdictions like the EU, India and the USA are actively considering new and comprehensive legal frameworks.
vi. While there is no comprehensive and sector-agnostic law for AI in the US, it has a lot more legal/policy activity happening through multiple efforts, which is being coordinated now.

IV. Policy Principles

Based on the interviews and the literature search, the following general ideas are being recommended to adopt and promote as policy principles for organizations using AI with geospatial data:

i. Ensure your organization's policy positions are in alignment with the growing consensus around the ethics and governance of AI technologies globally.
ii. Organizations should lead by example, and in good faith, build norms for ethical use of AI so that customers, people, and policy makers have strong reasons to trust the geospatial industry.
iii. Create tests and checklists for geospatial use-cases that enable companies to self-audit or could become a standard for third-party AI auditors.
iv. Advocate for government policies to be adaptive to the state of rapidly changing technology and stay cognizant of the new normal or enforceability of the regulations.
v. To promote innovation, advocate that government policymakers should trust the innovators first and then introduce regulatory controls only where abuses are noticed.
vi. Identify and classify use-cases or application areas by the risk of potential harm that can be used effectively by government agencies to calibrate regulatory/policy responses.
vii. Develop and promote good training data, benchmarks and tests to support the proliferation of AI technologies. Collaborate with other geospatial organizations on such initiatives.

Organizations should lead by example, and in good faith, build norms for ethical use of AI, so that customers, policymakers, and citizens at large, have strong reasons to trust the geospatial industry.

Glossary

Artificial Intelligence (AI): AI is the capability of a functional unit to perform functions that are generally associated with human intelligence, such as reasoning, learning and foresight that enables it to function appropriately in its environment.

Autonomous Vehicles: An autonomous vehicle is one that can guide and drive itself without human conduction.

Bias: Inclination or prejudice for or against one person or group, especially in a way considered to be unfair.

Convolutional Neural Network (CNN): Inspired by the organization of the neural networks in an animal's visual cortex. 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.

Deep Learning: is a subset 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.

Earth Observation: is the gathering of information about the Earth's physical, chemical and biological systems. It involves monitoring and assessing the status of, and changes in, the natural and human-built environment.

Edge computing: refers to data storage and processing at the edge of a network instead of cloud.

Ethics: Moral principles that govern a person's behavior or the conducting of an activity.

Federated Learning: Federated Learning is a machine learning setting where the goal is to train a high-quality centralized model with training data distributed over a large number of clients, each with unreliable and relatively slow network connections.

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.

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

GNSS Trace: GNSS (Global Navigation Satellite System) is a broad term encompassing different types of satellite-based positioning, navigation and timing (PNT) systems used globally. And, a record of location received from GNSS at a regular frequency or distance is a trace.

Hyperspectral: is the collection and processing of information from across the electromagnetic spectrum. The goal of hyperspectral imaging is to obtain the spectrum for

each pixel in the image of a scene, with the purpose of finding objects, identifying materials, or detecting processes.

LiDAR: Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) between objects. Works on the same principle as Radar.

Machine Learning (ML): is the field of study of algorithms that learn or improve through observations (and experience) automatically, without being explicitly programmed to do so. It is seen as a subset of artificial intelligence.

Point cloud: These are datasets that represent 3-dimensional objects or space through the X, Y, and Z geometric coordinates of a single point on an underlying sampled surface. Point clouds are a means of collating many single spatial measurements into a dataset that can then represent a whole.

Quantum computing: An area of computing focused on developing computer technology based on the principles of quantum theory, which explains the behavior of energy and material at the atomic and subatomic levels.

Reinforcement learning: Reinforcement learning is a field of machine learning concerned with how software agents ought to take actions in an environment so as to maximize some notion of cumulative reward.

SLAM: Simultaneous localization and mapping (SLAM) is the creating or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it.

Soft-law: Co-operation based on instruments that are not legally binding, or whose binding force is somewhat "weaker" than that of traditional law, such as codes of conduct, guidelines, peer review.

Supervised learning: is the machine learning task of learning a function that maps an input to an output based on example input-output pairs. It infers a function from labeled training data consisting of a set of training examples.

Synthetic-aperture radar (SAR): is a form of radar that is used to create two-dimensional images or three-dimensional reconstructions of objects, such as landscapes. SAR uses the motion of the radar antenna over a target region to provide finer spatial resolution than conventional beam-scanning radars.

Theory Guided ML: Machine Learning techniques that rely not only on a combination of virtual and physical data, but also on the underlying physical laws governing the problem (i.e. domain knowledge or theory). This results in a physically consistent model which requires far less data for training ML models.

Training data: is an initial set of data used to help an AI/ML algorithm learn and produce results.

Unsupervised learning: is a type of machine learning algorithm used to draw inferences from datasets consisting of input data without labeled responses.

Artificial Intelligence and Machine Learning Study

Artificial Intelligence and Machine Learning (AI/ML) have fundamentally changed the workflows in many tasks. and hence expand previous conceptions of limits, outcomes, scale and costs. Since 2013, the world has experienced the rapid growth of AI/ML applications in various technology domains. In the geospatial domain, a wide range of AI/ML use-cases and opportunities emerge with great promise in terms of innovation, break-through efficiency gains and addressing previously unsolvable problems.

In the geospatial domain, a wide range of AI/ML use-cases and opportunities emerge with great promise in terms of innovation, break-through efficiency gains, and addressing previously unsolvable problems.

At the same time, the COVID-19 pandemic has shown us that even the developed world isn't as resilient to big shocks as we would have believed a year back. It will be long before the world fully recovers from the economic, social, and direct impact of the pandemic, and some things may never be the same as before. High acceleration of digitization in all sectors, rapid growth of e-services as well as remote management and monitoring applications for people, assets, land use, natural events, etc., are irreversible trends and heavily depend on geospatial data and analysis using AI.

This WGIC research study summarizes current AI/ML practices and experiences in the geospatial industry and the emerging policy domains and challenges by tapping into the accumulated experience of the WGIC members, complemented with opinion leaders, leading academia and technology visionaries.

For the purpose of this study, we have combined elements from two previously published definitions of AI from the International Standards Organization (ISO) and Stanford

University[5] where Artificial Intelligence (AI) is defined as the capability of a functional unit to perform functions that are generally associated with human intelligence, such as reasoning, learning and foresight that enables it to function appropriately in its environment".

We also define Machine learning (ML) as the field of study of algorithms that learn or improve through observations (and experience) automatically, without being explicitly programmed to do so. It is seen as a subset of artificial intelligence.

1.1 Study Methodology and GeoAI Expert Consultations

As mentioned above, this WGIC research study summarizes current AI/ML practices and experiences in the geospatial industry along with the policy and regulatory aspects of AI and ML applications in the geospatial domain.

While the policies influencing AI/ML include the ones about data privacy and personal information, intellectual property control and protection, more recently, discussions about AI ethics and the impact of AI on the socio-economic fabric of society has taken center-stage. This study also provides an overview of different legislative efforts around the globe on regulating AI/ML technologies.

The findings of this research study by WGIC will be shared widely with relevant stakeholders globally to further define policy recommendations as well as best practices and guidelines for the geospatial industry. It will help the industry in realizing the potential of AI/ML technologies while staying true to its purpose of serving society. The methodology planned for this study was as follows:

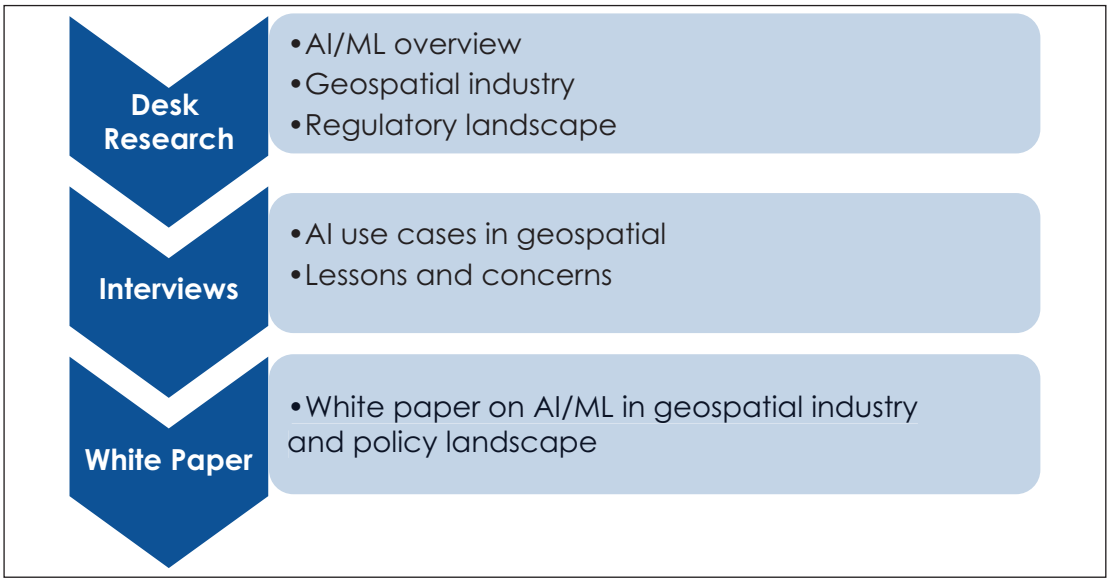


Figure 1: Methodology adopted for the WGIC AI/ML Research Study

5 https://ai100.stanford.edu/2016-report/section-i-what-artificial-intelligence/defining-ai and https://www.iso.org/

As GeoAI problems do not always easily fit into the standard AI/ML frameworks of computer vision or language analysis, and to understand GeoAI applications and its nuances, we conducted interviews with technical experts working with WGIC member organizations and then complemented those perspectives with other opinion leaders, leading academics and technologists.

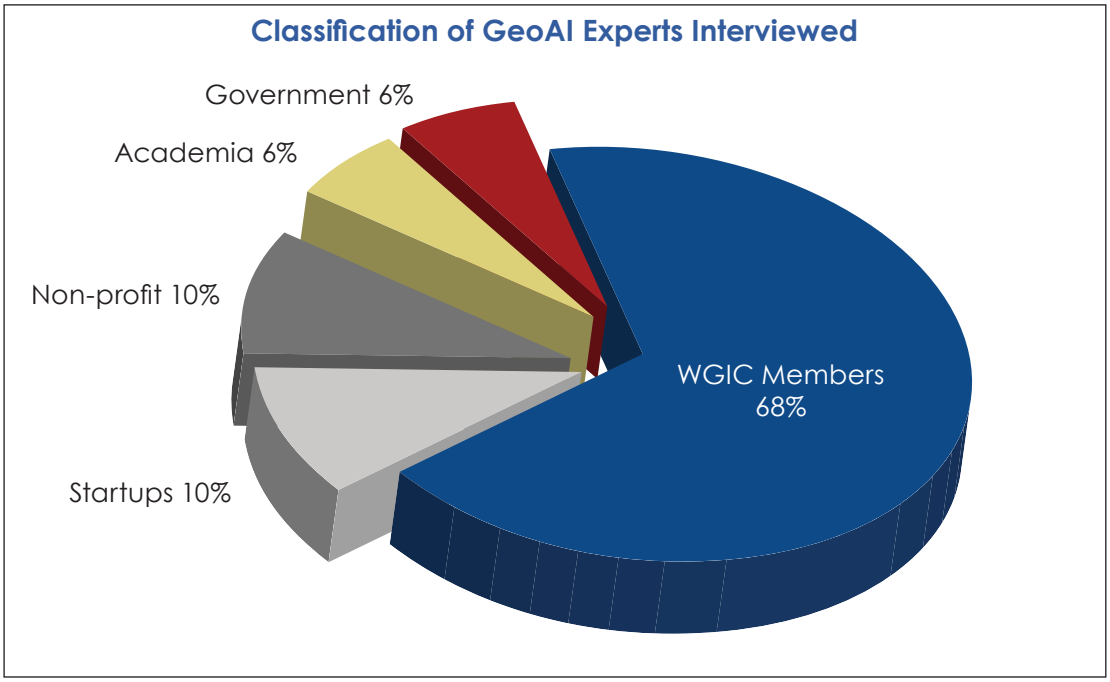


Figure 2: GeoAI experts interviewed by segment

Figure 2 presented above shows the distribution of experts interviewed by sector where WGIC members were all from medium and large enterprises within the geospatial industry.

This distribution highlights that during the research and consultation phase, conscious efforts were made to ensure resources and experts were from a diverse set of organizations, countries, jobs and fields. The purpose of these efforts was to ensure that our findings are representative and generalizable.

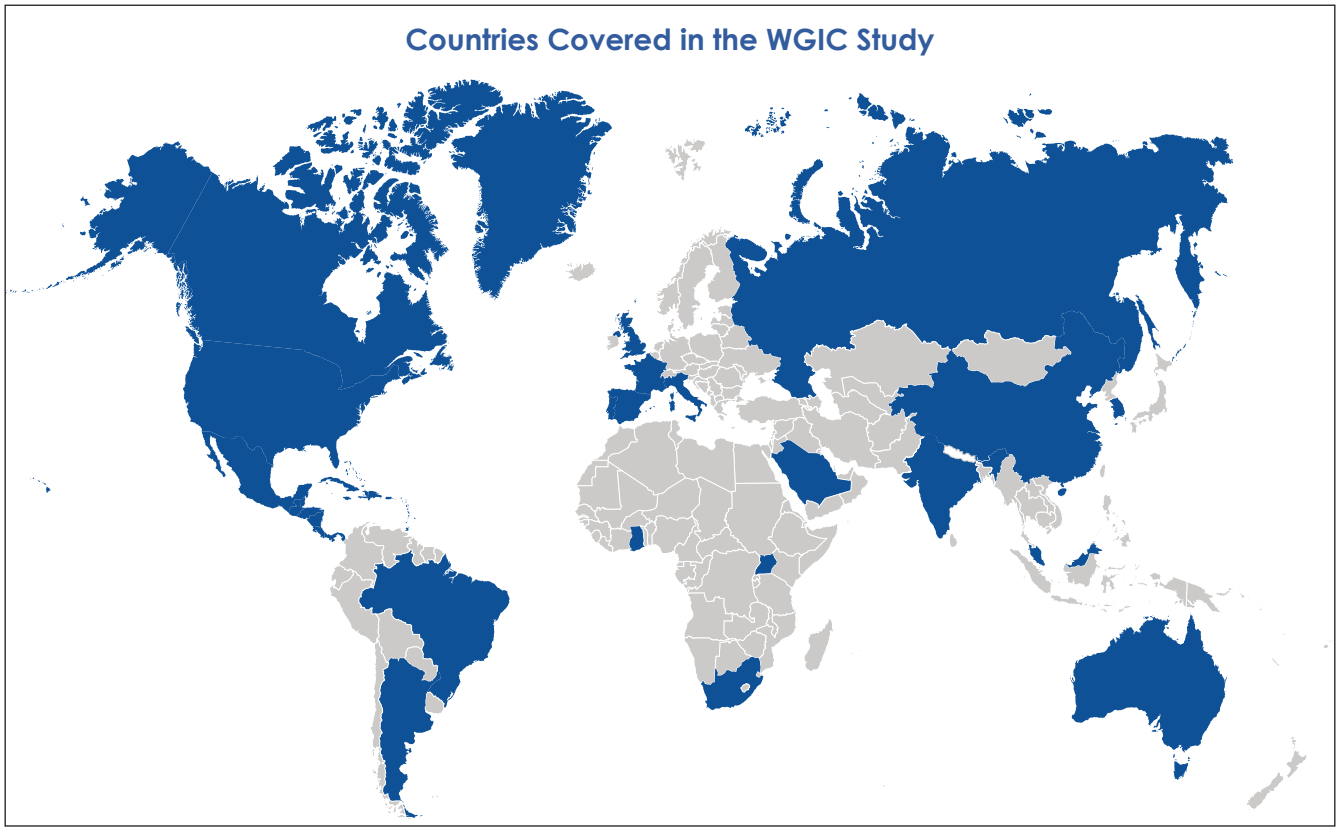


Figure 3: Jurisdiction covered for the purpose of this study

Figure 3 (above) shows the jurisdictions covered by the study. It includes the countries where experts being interviewed were currently employed, and the countries included in the AI policy landscape research conducted by the author. This reflects the good-faith effort made to ensure a globally representative study.

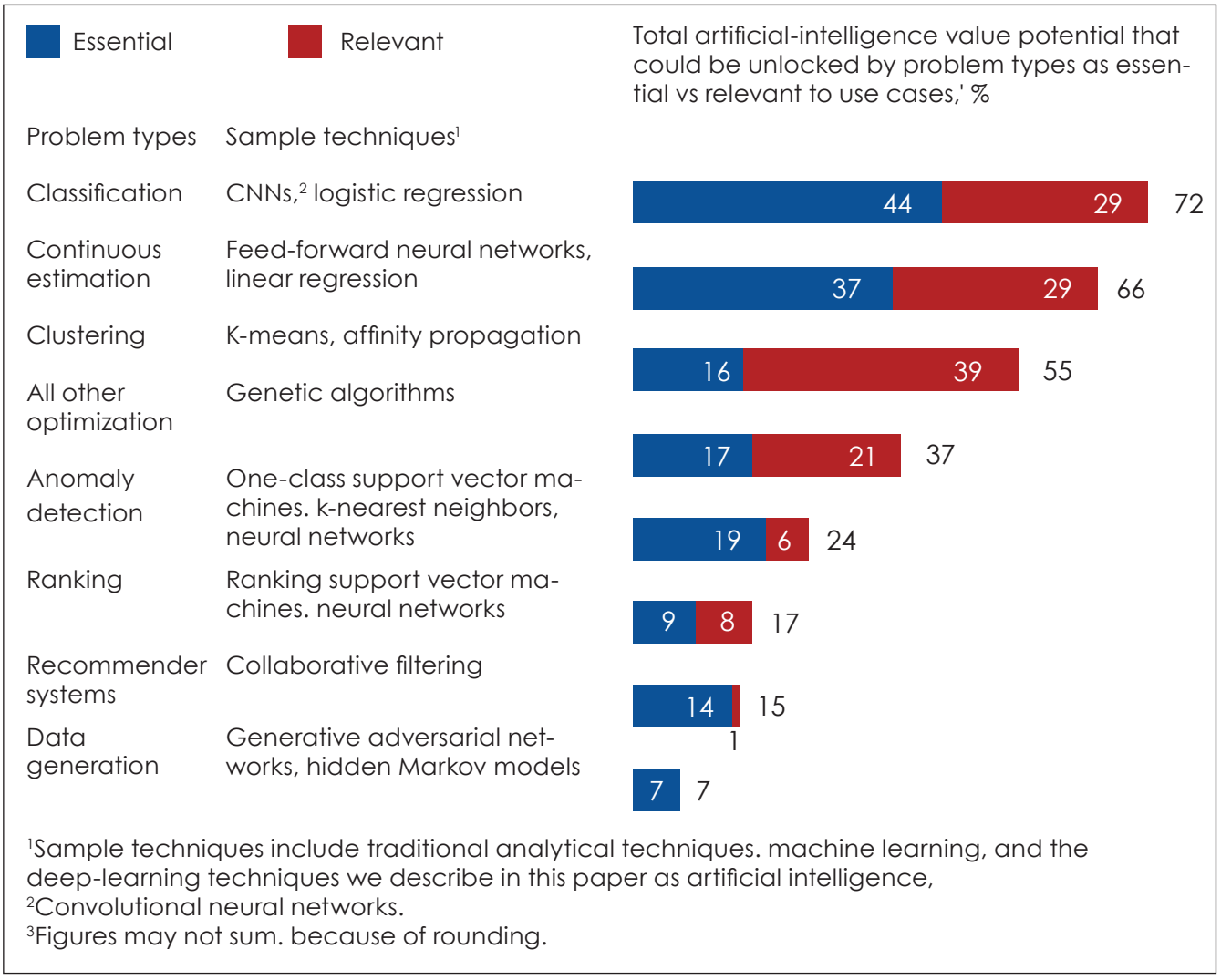
1.2 AI/ML Techniques

As defined earlier, AI is the ability of computers to perform tasks that typically require some level of human intelligence. Machine learning, at its core, is composed of various methods and techniques that allow computers to learn from data without being explicitly programmed to do so. Beyond the complex mathematical algorithms, AI/ML enable a machine to learn from text, images or sound. Imagine it as a machine that can sense its environment, learn and make predictions.

In the future, such systems may also be able to take independent action by controlling or influencing both software and the physical infrastructure it supports. As a general-purpose technology, AI/ML can be used to increase the efficiency, safety and quality of production processes in almost every industry.

Advances in AI within the last six to seven years have made it possible to unlock the potential of unstructured data, and to do so at scale. This has led to the accelerated adoption of the subfield of machine learning called "deep learning". This technique applies "deep" artificial neural networks, that are composed of dozens of connected computa-

tional layers, to learn and gather insights from large amounts of data. Deep learning has created the ability to very accurately detect objects and classify pixels at scale in geospatial data. Advanced variants of deep learning techniques include reinforcement learning, generative adversarial networks, graph convolutional networks, and transformers. The pace of research and development activity in the neural networks space is phenomenal and the recent breakthroughs in leveraging big data, sensors and user generated data, and cloud computing has rejuvenated the interest in AI. The following graphic outlines the major problem types and the AI/ML techniques used to solve those:



[1]Sample techniques include traditional analytical techniques. machine learning, and the deep-learning techniques we describe in this paper as artificial intelligence,
[2]Convolutional neural networks.
[3]Figures may not sum. because of rounding.

Figure 4: Source – McKinsey Global Institute Research (Mapping AI techniques to problem types)

1.3 Classification of AI/ML Techniques

AI/ML in the geospatial domain has largely been used to solve problems using structured and unstructured (e.g., images) data in broad categories mentioned in Figure 1. These also correspond well to the classification used earlier in this report i.e., descriptive, predictive and prescriptive technologies:

i. **Descriptive:**
   - **Clustering**: An unsupervised machine learning technique that processes large quantities of input data and identifies the meaningful clusters within them. For example, clustering techniques can be used to determine optimal locations for new factories or stores.

   - **Anomaly detection**: In the geospatial industry, detecting the anomalies in movement patterns and speed like unexpected detours, stops, etc., is very useful in applications like personnel monitoring, logistics, fleet management, etc.

ii. **Predictive:**
   - **Prediction/Estimation**: Based on a set of training data, predictions of the value of an output variable can be generated. In fact, as AI helps making predictions easier and cheaper, a lot of problems are being transformed into prediction problems to solve them using AI. For example, driving on the road is being converted into a prediction problem (i.e., how a vehicle in front or person on the road will behave) to build autonomous driving solutions.[6]

   - Classification: Based on a set of training data, new inputs can be automatically categorized as belonging to one of a set of categories. For example, machine learning classifiers can be used to create land use/land cover maps.

iii. **Prescriptive:**
   - **Optimization**: AI solves a large number of problems using optimization algorithms like gradient descent to prescribe an optimal solution.

   - **Recommendations**: Generating a route for a vehicle that creates the optimum combination of time and fuel use is a good example. In fact, most decision support problems are prescription problems as they make recommendations that assist in decision making.

The other problem types listed in Figure 4 are often considered as the sub-categories of the first four broad categories.

6 Agrawal, Ajay et al. Prediction Machines: *The Simple Economics of Artificial Intelligence* Harvard Business Review Press (2018). https://www.predictionmachines.ai/

Geo AI

Geospatial data plays a key role in the nexus that connects people, events and objects together. The vital importance of geospatial or location data gets captured well in the UK Ordnance Survey's brand re-positioning campaign tagline, "Everything Happens Somewhere".[7]

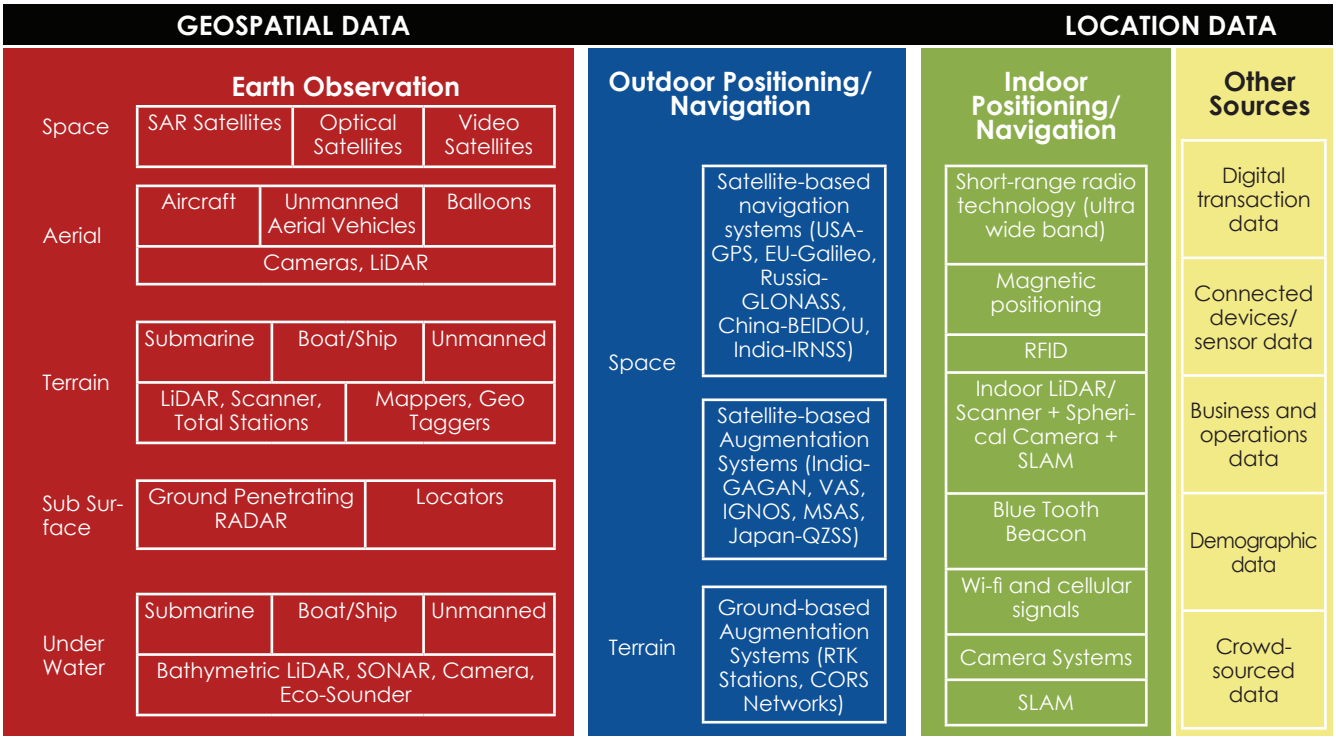


Figure 5: Source – GeoBuiz 2019 (Geospatial Industry Outlook and Readiness Index)

Currently, both the analysis and capture of geospatial data are witnessing exponential growth in all its sub-domains. Geospatial data can come in many forms and can be grouped in the following four categories: geometric, raster, spatial networks (or vector) and other. Examples of such data include Earth observation (EO) data, High Definition (HD) maps, point cloud data, road networks, parcel/building boundaries, GPS traces, and text and voice data with location references. Analysis and services using such data include navigation, urban computing, asset management, fleet tracking, geotagged social media data or location-based digital services.

With the increase in data and computing capacities, methods of analysis have also become more data-driven and exploratory than the previous paradigms of data analysis.

7 https://www.ordnancesurvey.co.uk/business-government/innovation/happens/about-everything-happens-somewhere

AI/ML is facilitating more sophisticated analyses, and rapidly replacing older analytical methods, as well as opening new frontiers in terms of use-cases that were not possible earlier to derive actionable insights and predictions from data.

2.1 Unique Aspects of GeoAI

Everything in the real world occupies some place in space and the physical proximity underpins a very real form of connectedness among objects, people and places, which can also span time. Geospatial data or quite often, spatiotemporal data and its analysis requires a very different way of reasoning than solving other AI/ML problems. To be analyzed properly, vector data that denotes the connectedness of objects, requires different kinds of algorithms like graph convolutional networks. GeoAI also remains an emerging discipline and working with domain experts is vital to solve geospatial problems.

Below is a short list of reasons why GeoAI tools and applications are different from those in other non-geospatial industrial applications:

i. **Data type:** As already stated, geospatial data deals with the physical location, proximity of people and assets in both space and time, making it dynamic as well.
ii. **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. Many individual companies have petabytes or even hundreds of petabytes of data routinely captured by sensors, devices and satellites, often dating back decades.
iii. **Higher dimensional data:** While the traditional geometry-based analyses use low-dimensional spaces, and therefore distances are not as significant in high-dimensional spaces (except when using hyperspectral data), the use of high-dimensional data is increasing in the Geospatial domain. When combined with real world data, both structured and unstructured geospatial data becomes more high-dimensional which adds to the complexity of AI/ML techniques necessary to solve a given problem.
iv. **Preprocessing for ML:** As most standard AI/ML tools are not geared to understand the concepts of geospatial-connectivity, spatial proximity, terrain, etc., geospatial data requires greater preprocessing than standard AI models.
v. **Real-time applications:** Many GeoAI applications like autonomous driving, predictive routing, and asset tracking require real-time processing and instantaneous results for decision making using the complex and structurally different data than text or images analyzed by standard AI models.
vi. **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.

Each of these aspects of geospatial data make GeoAI a highly interdisciplinary field bridging disciplines like computer science, engineering, statistics, and spatial science.

As this field focuses on real-world problems, the impact on society and the economy is very high and critical.

GeoAI is a niche and nascent field. The research community in this field is focused on methods to process, manage, analyze, and visualize geospatial (big) data. The domain has abundant opportunities to derive dynamic insights from complex spatiotemporal phenomena. GeoAI workflows comprise steps for data manipulation, data integration, exploratory data analysis, modeling and visualization. These methods are applied to spatiotemporal data of the specialized kinds and formats as listed above.

2.2 GeoAI Use-Cases

GeoAI applications are also disrupting several industries. The applications involve spotting trends, extracting features and predicting outcomes from a combination of geospatial and external data to support automation of tasks, asset and resource monitoring, disaster preparedness, risk management, market assessments, geospatial intelligence and other core business needs.

We asked the participants in this study to outline the common geospatial AI/ML use-cases that their organizations have been working on. This resulted in the following list of applications:

i. **Automatic map updates:** An important application of AI/ML when working with satellite or aerial imagery, GNSS trace data, terrestrial LiDAR and other sensor data, is the ability to create digital maps by automatically extracting information about roads, buildings and terrain, etc. A trained deep learning model can be applied to this data to maintain up-to-date mapping information.

GeoAI is a highly interdisciplinary field bridging disciplines like computer science, engineering, statistics, and spatial science. As this field focuses on real-world problems, the impact on society and the economy is very high and critical.

Fig 6: Source – Mapster Project @MIT

ii. **Semi-automatic analysis and extraction of geospatial information:** Geospatial imagery, 3D point clouds and remote sensing data are essential in geospatial applications like urban planning, environmental monitoring, construction and precision agriculture. Techniques like Convolutional Neural Networks (CNNs) and Graph CNNs are being used to analyze raster, vector and point cloud data, to detect geospatial features, and to extract information from the data. As these algorithms are also not able to model critical phenomena like spatial heterogeneity and edge effects properly, human-in-the-loop systems are preferred right now.

iii. **Asset tracking and management:** In many asset-intensive industries – such as energy, shipping, transportation, communications, and the public sector – the ability to track, monitor and visualize business objects (vehicles, equipment, buildings, and other physical property) with geospatial information is critical to improving efficiency and decision-making. Remote sensing/GPS data and aerial imagery combined with AI/ML can help businesses better manage asset availability and utilization and mitigate any risks involved with loss, downtime or delays.

iv. **Disaster prevention, preparedness and management:** For quick and efficient response, as well as for recovery after any natural or artificial disasters like wildfires, droughts,

storms, oil spills etc., one of the most important requirements is the ability to process spatial data in real or near real-time. AI/ML tools can not only help in providing rapid responses to better manage disasters but can also help make better, smarter and timely decisions to prevent future occurrences.

v. **Utilization and preservation of natural resources:** Effective utilization and preservation of natural resources like farmlands, forests, water reservoirs, etc., are an important aspect in the economic stability and growth of any country or region. Satellite images, aerial and remote sensing data provide the necessary information which, combined with deep learning (the set of most prominent neural network-based AI techniques), can provide public agencies and businesses the ability to make decisions that will result in sustainable development and growth/preservation of natural resources.

vi. **Risk management:** Businesses across disparate industries deal with various operational risks on an ongoing basis like weather/disaster disruptions, civil unrest, crime, fraud etc., many of which have a geospatial component. These risks not only impact business continuity and profitability but can also impact how insurance companies price policies. AI/ML based risk models that incorporate geospatial information can help businesses better manage risks and help insurance companies set proper premiums and handle claims more efficiently.

vii. **Predictive routing and logistics planning:** Best routes in transportation and logistics often involve an optimized balance of distance travelled, quality of route and total time taken. AI/ML may help predict the best and safest routes for an origin-destination spatial matrix by considering variables like number of stops, traffic, accidents, construction, time of day, weather, speed limits etc.

viii. **Autonomous vehicles:** Autonomous vehicles is one of the popular research areas of AI/ML in the geospatial domain today. Autonomous driving/navigation is heavily dependent on GPS but wherever GPS fails, or the system encounters a previously unknown or a very dynamic environment, then simultaneous localization and mapping (SLAM) is required for navigation. It involves constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it. SLAM involves the use of deep learning techniques on geospatial and real-time road infrastructure imagery to localize and map a vehicle's path using real-time automated decisions.

ix. **Market analysis and growth planning:** Businesses in various industries like retail, banking, food and beverage, healthcare, etc., make growth and expansion decisions, like where to open a new store, branch or facility, based on hotspots of certain consumer behavior. By combining demographic, socioeconomic and geospatial data and using AI/ML techniques, businesses can identify suitable sites and locations for expansion by not only considering consumer purchase patterns but also consumer mobility and access.

GeoAI can provide public agencies and businesses the ability to make decisions that will result in sustainable development and growth/ preservation of natural resources.

x. **Geospatial awareness and intelligence:** Public organizations like law enforcement agencies and public health organizations rely on geospatial information to track crime and public health issues. Application of AI/ML to the underlying data can allow public organizations to better predict and combat crime and public health issues. These applications, however, are sometimes controversial and to ensure accountability and fairness, it is vital to first make AI explainable.

xi. **Maritime monitoring and management:** AI/ML is used to automatically monitor ports and coastlines around the world to track the movement and patterns of maritime shipping vessels. AI can help determine patterns in port activity or on strategic routes and

monitor anomalies to identify suspicious activities based on ship count patterns or vessel behavior.

xii. **Military and defense applications:** Geospatial intelligence is a critical component of planning in defense and military operations. AI algorithms help with change detection in satellite or aerial imagery that is an important piece of modern reconnaissance technologies. Monitoring critical infrastructure from above and assessing damages are all part of intelligence gathering.

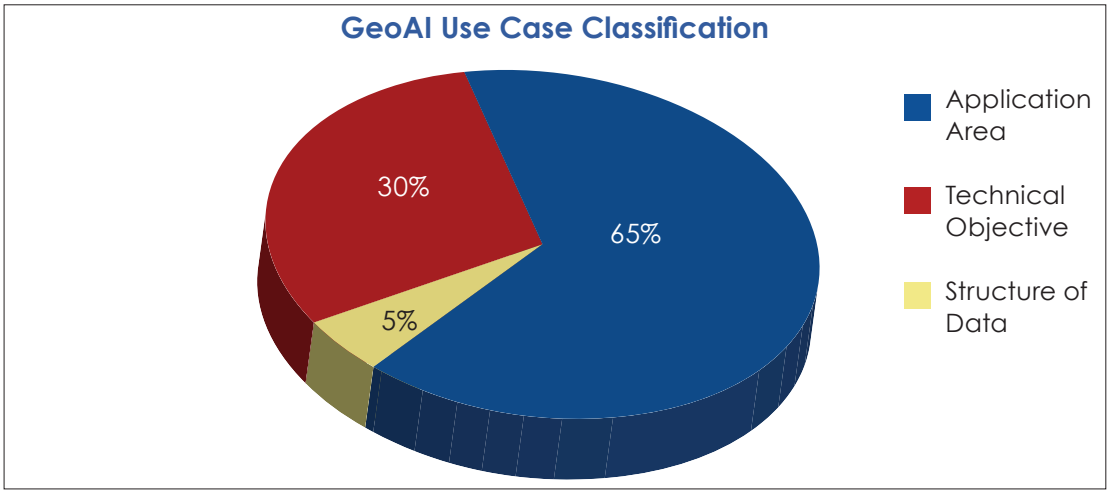


Figure 7: Classification adopted for GeoAI use-cases by organizations participating in the WGIC study

As end-customers identify their tasks based on the application areas like road network mapping, land cover use or asset tracking, the majority (65%) of participants of this study said their organizations prefer classifying the AI/ML use-cases based on such application areas. Thirty percent of the participants took a more supply or internal expertise driven approach for classification by technical objectives or techniques used, e.g., object identification, point cloud classification, etc. The remaining 5% preferred to classify their use-cases based on the structure of data being analyzed, as data pre-processing takes the most time.

2.3 Trends and Forecasts

With the continued demand and interest in geospatial AI/ML technologies, many new applications and use-cases are emerging that will impact the domain in the near to long-term. We asked the participants from our study to share their perspectives on technology trends in the geospatial industry. Here is a summary of the emerging use-cases and applications highlighted by these GeoAI experts:

i. **Increased automation:** Many of the current geospatial AI/ML tasks require some aspects of human intervention to get adequate results. Advances in AI/ML techniques will allow for full automation in areas like mapping, object identification, feature/attributes extraction in the objects identified e.g. number of lanes in a road, or condition/damages in the road or building.

ii. **Better natural resource management:** With advances in deep learning techniques and

By recreating our world in a computer system, geospatial AI/ML techniques can be applied to predict outcomes based on variable conditions.

easy access to satellite imagery and remote sensing data, geospatial AI/ML will find greater adoption in industries like agriculture, forestry, climate change, etc., e.g., those that involve tracking and managing natural resources.

iii. **Real-time applications:** Several of the current geospatial AI/ML techniques require days, weeks or even months to turn geospatial data into actionable results. Increasing computing power, edge computing, better algorithms and ML support in field equipment will allow for the development of real-time and near real-time geospatial AI/ML applications.

iv. **More data for AI/ML:** With the advancement of highly-capable miniaturized remote sensing, imagery and LIDAR systems and satellites, businesses will have access to a greater collection of real-time geospatial and remote sensing data with increasingly higher resolution/quality that will allow for new geospatial AI/ML use-cases currently not possible.

v. **Accessibility of AI/ML applications:** Application of geospatial AI/ML techniques to business problems currently requires trained data scientists and machine learning engineers. With pre-trained ML models integrated with GIS software, geospatial AI/ML will become accessible for all, from a small farmer to an executive at a large enterprise.

2.4 Breakthrough Technology Advancements

Advancements in AI/ML, geospatial and high-performance computing technologies will continue to push the GeoAI field forward. Some of these technological advancements will lead to breakthrough applications in 2030 and beyond. Study participants reported such breakthroughs as:

i. **Ensuring Data Veracity:** The degree to which data can be accurate and trustworthy is extremely critical for AI algorithms trained to be effective and unbiased. A modified copy of data could lead to negative outcomes. Developments in making data more trusted and secure when sharing it with other applications will result in fewer data silos.

ii. **Increasing Sample Efficiency:** Current AI models require increasingly large amounts of data to be trained for improving their results. Relative to machines, humans need significantly smaller amounts of data, and are much more sample efficient. The computational costs of training algorithms are very high and it is becoming unaffordable for small organizations. Therefore, research breakthroughs in increasing sample efficiency of algorithms would be of great value for smaller organizations and therefore increase AI's democratization.

iii. **Custom GPUs or Application-specific integrated circuit (ASIC) chips:** GPUs have long been the chip of choice for performing AI/ML tasks. Advancements in general-purpose GPUs (GPGPUs) and AI-specific GPUs and ASICs are expected to accelerate the adoption and use of resource-intensive deep learning techniques. Such processors/chips for efficient geospatial data analysis will be in the market in 2-5 years.

iv. **Digital twins:** Digital twin technology will allow practitioners to build digital representations of physical objects like vehicles, equipment, buildings, factories, and even entire cities/regions. By recreating our world in a computer system, geospatial AI/ML techniques can be applied to predict outcomes based on variable conditions for finding efficiencies as well as other benefits.

v. **Hyperspectral Satellite Imagery:** The deployment of low-cost satellite constellations capable of hyperspectral imagery at high ground resolutions will lead to a revolution in

high-frequency Earth observation and prediction AI/ML applications for various industries.

vi. **Edge Computing:** Edge computing promises to make near real-time geospatial AI/ML applications possible by moving the computation of ML techniques to field equipment and servers closer to the satellites and sensors that are generating the geospatial and remote sensing data.

vii. **LiDAR-capable consumer devices:** Wider adoption of Light Detection and Ranging (LiDAR) sensors in consumer devices like smartphones and tablets is expected to increase the availability of massive user-generated real-time geospatial data that could lead to unique geospatial AI/ML applications. Apple is already including LiDAR sensors in its latest series of iPhones and iPads, and others will follow soon.

viii. **Knowledge Guided Machine Learning:** Current AI/ML approaches build an understanding of the observed phenomena from the beginning using patterns in data. This new paradigm explores how to utilize the treasure of accumulated scientific knowledge that already exists to significantly improve the performance of machine learning methods.

ix. **Quantum Computing:** Quantum computers are theoretically designed to manage huge amounts of data at exponentially faster rates than classical computers. Quantum computing will facilitate geospatial AI/ML applications dependent on huge multi-dimensional data sets and complex models.

2.5 Business Concerns

Businesses across several industries are increasingly reliant on location and geospatial data to gain real competitive advantages. Advances in geospatial AI/ML capabilities are expected to accelerate the general adoption of both traditional and geospatial AI/ML within these industries. For businesses and their leaders that are focused on improving operational efficiencies or creating competitive advantages, the geospatial AI/ML revolution offers unlimited opportunities. Close to 80% of the organizations represented in our study, and 72% of WGIC Member organizations have a high level of interest in using AI/ML technologies and are making significant resource commitments for it.

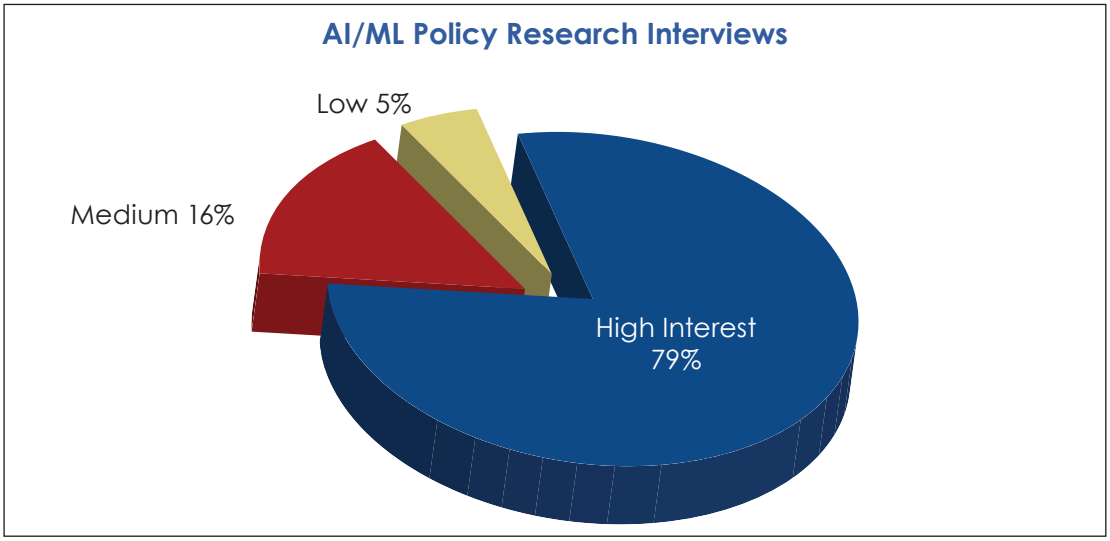


Figure 8: Organizational Interest in AI/ML Applications in Geospatial Domain

While the demand for geospatial AI/ ML applications is high, the risks due to the scarcity of sufficiently trained data scientists and engineers are also high relative to the consumer tech industry.

At the same time, businesses prefer predictability of operating environments, competition and resources. However, these applications also come with several challenges and concerns for businesses that affect their prospects of generating successful results. Following is a list of concerns highlighted by the interview respondents during the course of this study:

Technological concerns

i. Veracity and quality of data are critical to ensure the results are accurate and unbiased.
ii. The inability of AI/ML methods to explain the derived results in a way that is comprehensible or explainable to decision makers.
iii. A gap in reliability, consistency and accuracy of results and inability to effectively detect and track errors and biases as they arise within the various AI/ML techniques.
iv. Government related concerns
v. Lack of clarity on the underlying legal risks and liabilities (data/technology provider vs user) as a result of problematic AI/ML outputs.
vi. Dependence on public data sets shared by governments and lack of clear guidelines on whether such data will continue to be available in the future.
vii. As government is often the biggest customer, absence of guidelines from government in terms of investment priorities or policies make some projects/applications inherently risky.
viii. Governments around the world are seriously considering regulating AI systems to ensure fairness of outcomes – something that cannot be achieved without inclusion of a diverse group of people in the product development process.

Market risks

i. Some innovation (especially in the consumer space) in geospatial AI/ML is being driven by several non-geospatial companies which might lead to various unforeseen issues in the future e.g. monetization of personal data, consumer profiling, etc.
ii. While the demand for geospatial AI/ML applications is high, the risks due to the scarcity of sufficiently trained data scientists and engineers are also high relative to the consumer tech industry.
iii. Similar to the AI product development in other domains, one of the key problems with building and managing GeoAI applications is that if the diverse inputs (geography, cultural, gender, race) do not get included at the design stage and onward, this can lead to unfair outcomes later for the groups that were not included in the product development process. This results in not being able to address the needs of all users, which can then lead to market backlash given public sentiment in support of inclusion
iv. The slow pace of hardware developments/improvements specific to the geospatial industry result in an inability to keep up with the growing demands of improving AI/ML techniques.

Supply/Resource related concerns

i. Lack of a standardized academic curriculum that focuses on geospatial AI/ML as its own discipline.
ii. The resource divide in AI has been increasing, and is slowly becoming prohibitively expensive for small organizations to train their models on large datasets, e.g., OpenAI's famous general-purpose natural language processing model GPT-3 released in June 2020 cost $12 million to train[8].
iii. Lack of clear understanding within the organization on how the various AI/ML processes work or how best to utilize AI/ML technologies.

8 https://venturebeat.com/2020/06/11/openai-launches-an-api-to-commercialize-its-research/

AI Policy Scan/Landscape

3.1 Overview and Analysis

The 21st century has witnessed an unprecedented rate of digitization across almost all aspects of people's lives, in our economies and society at large. Since its inception, the WGIC and its Policy Committee have made sure to provide the geospatial industry with insights about this accelerated pace of digitization, the opportunity it presents and how policies and laws regulating these phenomena are evolving.

In 2019, the WGIC policy report on "Data Economy"[9] underscored how digitization in various domains and consequent applications using the collated data from multiple sources is the way forward for the geospatial industry. That report referenced increased data sharing among stakeholders in order to create high returns, leading to a reformulation of existing business models and policy frameworks. It also outlined how the accelerated use of AI/ML would occur, laying the groundwork for this study.

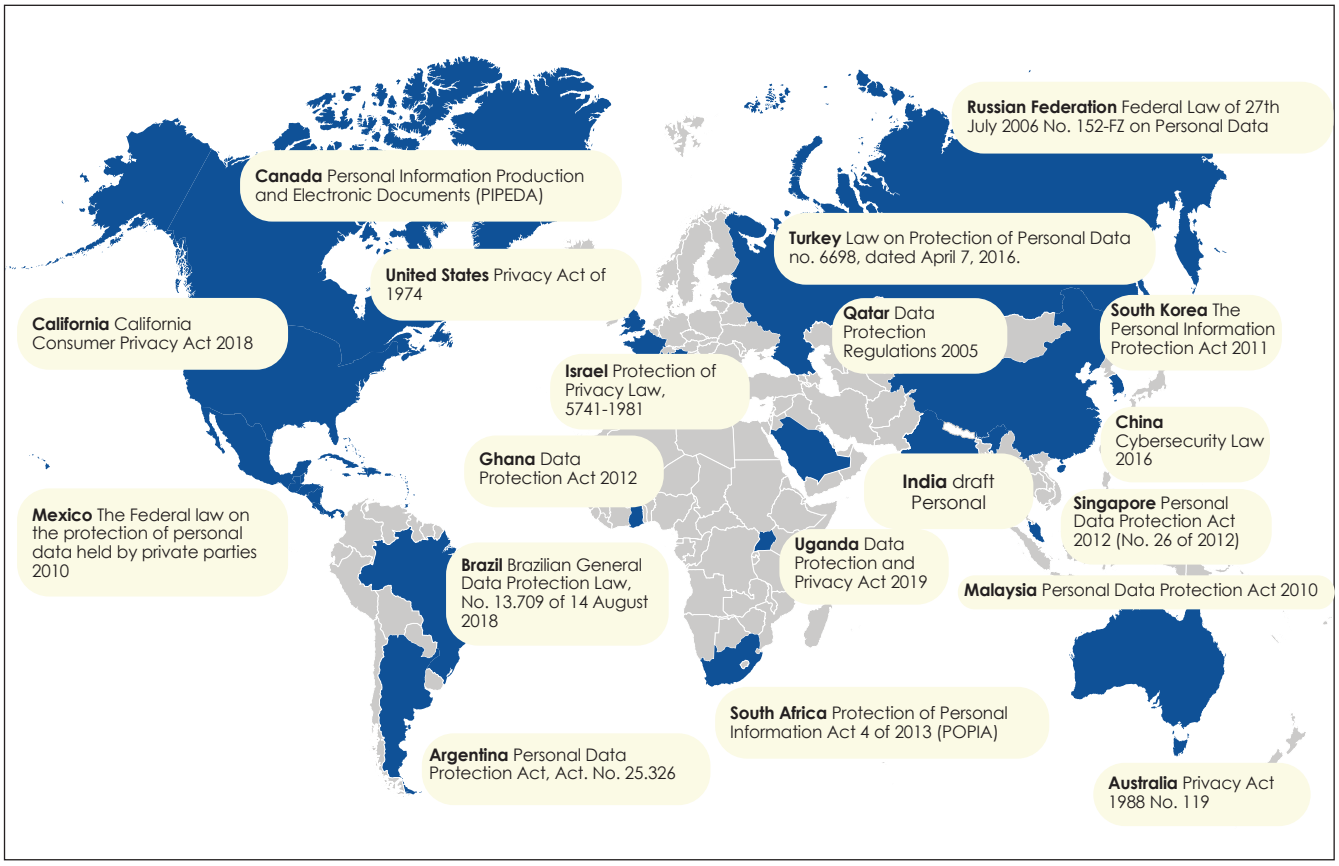


Figure 9: Jurisdictional coverage of WGIC report on Geospatial Information and Privacy

9 https://wgicouncil.org/wp-content/uploads/2019/05/Policy-Report.pdf

Data is the oil of an AI economy, so it is important to understand the policy issues around it. Almost all the jurisdictions we examined for this study have enacted data protection and privacy related laws, something that WGIC has studied in detail and presented as part of its earlier report titled, "Geospatial Information and Privacy: Policy Perspectives and Imperatives for the Geospatial Industry"[10] (Figure 9).

The data privacy report said that while legislation is generally enacted by countries independently, the overarching logic and content are quite similar because the underlying basis is for peoples' rights over their data. Similarly, in this study, we found that the broad strokes of policies governing AI/ML are similar around the world.

We started this study by examining the laws and policies on AI governance in six jurisdictions that are home for most WGIC Members. These jurisdictions are — Australia, the European Union, India, South Korea, the United Kingdom and the United States of America. We then expanded the review to include Brazil, China, the Middle East and Singapore to ensure broader global representation. We analyzed policy papers, laws, regulatory proposals, and soft law initiatives undertaken in these countries, to understand the legal approaches to AI governance around the globe.

We also looked again at the data protection laws. While almost all countries have data protection laws, India and the USA do not have a comprehensive federal data protection law. Both of these countries, however, are considering such comprehensive and holistic data protection legislation. India has enacted the Information Technology (Reasonable Security Practices and Procedures and Sensitive Personal Data or Information) Rules, 2011. This law generally suffers from weak enforcement and inadequate obligations tailored to contemporary data processing techniques. Further, this law is only applicable to certain private sector entities, and not data controllers at large. Additionally, we observed that some jurisdictions also check and control the use of geospatial information through regulations.

After analyzing multiple documents for each jurisdiction, we created a table (Table 1) to determine the level of their regulatory preparedness for promoting and regulating the use and deployment of AI. Our analysis included surveying policy papers, laws, regulatory proposals, and soft law in the above-mentioned jurisdictions.

All the jurisdictions examined for the purpose of this analysis have released a policy or a national strategy document on AI development, use or regulation. The appropriate decision-making authority in each of the six jurisdictions have issued white papers and policy proposals that set out national AI strategies from the point of view of social and economic growth.

Assuming robotics as a generic technology related to AI, South Korea is the only nation which has enacted a sector agnostic law on development of AI and promotion of investment and innovation. This is the Intelligent Robots Development and Distribution Promotion Act, 2008. So far, no other country has enacted such a broad law governing AI.

10 https://wgicouncil.org/wp-content/uploads/2020/03/Geospatial-Informaion-and-Privacy-report-Final.pdf

This creates a window of opportunity for the geospatial industry to develop consensus on key AI policy ideas and principles, and engage with policymakers on the substantive issues of concern during this nascent phase of AI policy development.

While adopting sector-agnostic AI laws could take time, application-area specific AI legislations has been enacted largely in the domain of autonomous vehicles, health-care, and facial recognition technologies. Australia, the UAE and the USA are three countries that have enacted such sectoral laws.

The below table provides a quick overview of the legal approaches to AI governance across the jurisdictions studied for the purpose of this study.

	AUSTRALIA	BRAZIL	CHINA	EUROPEAN UNION	INDIA	ISRAEL	QATAR	SAUDI ARABIA	SINGAPORE	SOUTH KOREA	UNITED ARAB EMIRATES	UNITED KINGDOM	UNITED STATES OF AMERICA
AI Policy/Strategy Documents or Whitepapers	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Enacted AI Laws (sector agnostic)				✓						✓			
Enacted AI Laws (sectoral/issue specific)	✓					✓			✓				
Regulatory Proposals/Draft Laws on Privacy		✓	✓			✓	✓						
Enacted Laws on Data Protection/ Governance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Soft law on AI (Guidelines and Directives)	✓			✓	✓			✓		✓			

Table 1: Policy preparedness for AI Governance and data privacy

Additionally, jurisdictions like the EU, and the USA are actively considering new legal frameworks for comprehensive data privacy laws. Another policy response option is that while the real policies are shaping up, some countries/jurisdictions have issued soft guidelines for sector/issue specific governance of AI. Following are the jurisdiction specific policy landscape analyses:

3.2 Australia

Multiple Australian government agencies have released official white papers, strategy documents and policy guidelines on the use of AI and ML across sectors. The Australian

Human Rights Commission[11] suggested a renewed human rights framework to tackle policy challenges posed by AI to people, society, and the economy. It outlines three key principles for any potential regulation in this domain. These are— (i) regulation must seek to protect human rights; (ii) it should be 'clear and enforceable';[12] and (iii) co-regulation and self-regulation should seek to preserve human rights and foster 'ethical decision making'. Additionally, they have also examined the potential causes of algorithmic bias and measures to mitigate harm.[13] Australia also has well-defined laws for autonomous vehicles.

In 2019, the Department of Industry, Innovation and Science also released a Discussion Paper on an ethics framework for AI.[14] This Discussion Paper outlines the following core principles for AI to ensure it is net positive in terms of benefits, fair, puts people first, transparent/explainable and that the companies using such systems are held accountable for any harm inflicted on people.

3.3 Brazil

In September/2019, the Brazilian Government enacted the General Data Protection Law (LGPD).[15] The main objectives of this law are:

- Ensure the right to privacy and protection of users' personal data, through transparent and secure practices, guaranteeing fundamental rights.
- Establish clear rules on the processing of personal data.
- Foster economic and technological development.
- Establish unique and harmonious rules on the processing of personal data, by all agents and controllers that process and collect data.
- Strengthen the security of legal relationships and trust of the holder in processing of personal data, guaranteeing free initiative, free competition and the defense of commercial and consumer relations.
- Promote competition and free economic activity, including data portability.

Currently, proposed legislation (LAW NO.21/2020)[16] is being considered that establishes the principles and rights for the use of AI in Brazil. Additionally, Brazilian government agencies are also working on an AI strategy document that would provide guidelines on the use of AI across different sectors of the Brazilian economy.

11 https://www.humanrights.gov.au/sites/default/files/document/publication/AHRC-Human-Rights-Tech-IP.pdf

12 https://tech.humanrights.gov.au/sites/default/files/inline-files/TechRights2019_DiscussionPaper_Summary.pdf

13 https://humanrights.gov.au/our-work/rights-and-freedoms/publications/using-artificial-intelligence-make-decisions-addressing

14 https://consult.industry.gov.au/strategic-policy/artificial-intelligence-ethics-framework/supporting_documents/ArtificialIntelligenceethicsframeworkdiscussionpaper.pdf

15 http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2018/lei/L13709.htm

16 https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=1853928

China's AI Plan talks about "building a robust framework for intellectual property protection in the AI industry (such as establishment of 'AI public patent pools')".

Other legislation called the "AI Law, establishing principles, rights and obligations for AI usage in Brazil"[17] is also being considered by the Brazilian Senate and is much further along as a vote on it is expected soon.

3.4 China

In the past few years, there have been several policy developments around AI development and use in China. Various agencies of the Chinese Government have issued policy briefs, white papers and strategy documents to outline a plan for AI research and development, and mainstreaming across several sectors. Some of these documents have also discussed the need for ethical and technical frameworks for AI proliferation. Some of these policy and strategy documents are as follows— "Three-year Action Plan for Internet+AI", "Guiding Opinions on Promoting the Deep Integration of AI and the Real Economy", "Guidelines for National New Generation AI Innovation and Development Pilot Zone Construction Work", the "Next Generation AI Development Plan", "Three-year Action Plan for Promoting Development of a New Generation AI Industry (2018-2020), and "The White Paper on AI Security Standardization (2019)".

The Next Generation Artificial Intelligence Development Plan (AI Plan)[18] was released by the Chinese State Council in 2017. The AI Plan acknowledges the potential of AI as a key driver of industrial transformation and social productivity. According to the AI Plan, emerging technologies such as AI have enormous potential in areas of education, environment protection, delivery of public services, healthcare, and urban life.

The AI Plan also seeks to devise adequate regulatory and ethical frameworks around AI use and development. It also provides for further research and collaboration on various rights and obligations around AI use such as civil liability, criminal liability, informational privacy and data security. It also discusses the possibility of the introduction of tax incentives for the AI industry, development of industry-wide technical standards, and building a robust framework for intellectual property protection in the AI industry (such as establishment of "AI public patent pools")

Further, in 2017, the Chinese Ministry of Industry and Information Technology issued the "Three-year Action Plan for Promoting Development of a New Generation AI Industry (2018-2020)" (Action Plan). It discusses China's plan for the integration of AI in the manufacturing industry[19] including the development of autonomous and "networked vehicles", UAVs, service bots, smart home services, etc.

Sectoral guidance

According to the AI Security Standardization White Paper (2019)[20], agencies of the Chi-

17 https://www.camara.leg.br/propostas-legislativas/2236340: it is called the AI Law, establishing principles, rights and obligations for the AI usage in Brazil

18 http://fi.china-embassy.org/eng/kxjs/P020171025789108009001.pdf & https://flia.org/wp-content/uploads/2017/07/A-New-Generation-of-Artificial-Intelligence-Development-Plan-1.pdf

19 19 https://www.newamerica.org/cybersecurity-initiative/digichina/blog/translation-chinese-government-outlines-ai-ambitions-through-2020/

20 https://cset.georgetown.edu/wp-content/uploads/t0121_AI_security_standardization_white_paper_EN.pdf

nese Government have initiated regulation or regulatory proposals across several sectors. For instance, the Chinese Civil Administration has released "Interim Provisions on Issues Related to the Management of Civilian Unmanned Aircrafts" and a host of other regulations at the intersection of civil aviation and AI. For the banking and finance sector, the Government has released "Guiding Opinions on Regulating the Asset Management Business of Financial Institutions". The Chinese Ministry of Industry and Information Technology, in collaboration with the Ministry of Public Security, and Ministry of Transport, have developed the "Administrative Rules of Road Testing of Intelligent Connected Vehicles (for Trial Implementation)".

Policy developments related to geo-spatial information

Surveying and mapping activities in China can only be carried out with necessary authorization as laid down in the Chinese Surveying and Mapping Law.[21] The law also provides guidelines for foreign entities seeking to conduct surveying activity in China. China's law of Surveying and Mapping (2017)[22] regulates the procedure of surveying and mapping, regulates geospatial information collection and use, and lays down certain guidelines for such activities carried out by an "unmanned vehicle".[23] Further, the "Notice to Enhance Management of Producing Testing and Application of Automatic Driving Maps (2016)" is another policy which governs map navigation data processing (map data). Also, in 2014, the State Council general office issued a document for promoting the development of the Geographic Information Industry. It rightly recognizes the needs for investment in research and development, regulatory changes and incentives for the private sector.[24]

3.5 The European Union (EU)

In 2018, European Commission (EC) adopted the Strategy for a Coordinated Plan for the purpose of AI development in Europe. It is one of the primary policy documents which calls for a legal and regulatory framework to address challenges posed by emerging technologies, and to develop national AI strategies for EU Member States. It also recognizes the potential pitfalls of mainstreaming AI and its impact on jobs. Accordingly, the Plan proposes skill development and training to sustain the workforce in a new technological era. In December 2018, the EU's High-Level Expert Group on Artificial Intelligence issued draft guidelines on AI ethics and principles for creating trustworthy AI.[25]In 2019, the EU also released a Communication titled "Building Trust in Human Centric Artificial Intelligence" which emphasizes the need to preserve fundamental rights while developing emerging technologies. It discusses the value of coordination and collaboration with EU Member States. In 2018, the EU released a Staff Working Document on "Liability for Emerging Digital Technologies" which examines possible liability frameworks in the age of AI and automated decision making.

The recent EU Directive on Open Data and the Re-Use of Public Sector Information de-

21 Refer to the 2002 law as well, The National Administration of Surveying, Mapping and Geoinformation of China, Surveying and Mapping Law of the People's Republic of China

22 https://www.geospatialworld.net/news/chinas-new-mapping-regulations-heres-what-you-need-to-know/)

23 http://ggim.un.org/meetings/2018-WG-Legal-Policy-Framework/documents/policy_in_China.pdf

24 http://www.gov.cn/gongbao/content/2014/content_2600054.htm

25 https://ec.europa.eu/futurium/en/system/files/ged/ai_hleg_draft_ethics_guidelines_18_december.pdf

velops a legal framework around the use of public sector data and can potentially impact the geospatial industry. It specifically covers the regulation of "high-value datasets" including geospatial data and states that owing to their high commercial potential, the EC will be working with Member States across the EU to whitelist specific "high-value datasets" that can be made easily accessible and re-usable across the EU .[26]On 20 January 2021 European Parliament adopted a resolution on AI to address the questions related to interpretation and application of international law . A month earlier new legislation, Digital Services Act, was also introduced in the European Parliament. It introduces explainability requirements that a "clear and specific statement of reasons" be provided to users any time their content is removed or disabled. It also adds new rules for hosting online content which includes user-contributed content and advertising too . Additionally, the Brookings Institution reported that the European Commission (EC) has made AI oversight a priority, and is expected to put forth legislation in the first half of 2021.

3.6 India

Currently, India has no holistic law which regulates AI or emerging technologies. A proposed comprehensive data protection legislation, the Personal Data Protection Bill, 2019 ("PDP") is being considered. The PDP has been drafted along the lines of the EU General Data Protection Regulation (GDPR). Unlike the GDPR, however, the PDP does not contain specific provisions on automated decision-making or algorithmic harm.

Developments in AI policymaking and strategy have been scattered and often ad-hoc. India has released the National Strategy for Artificial Intelligence,[27] a Working Document Towards Responsible AI,[28] and another Working Document for Enforcement Mechanisms for Responsible #AIforAll.[29] Among other things, the #AIforAll document proposes the creation of an Oversight Body to develop standards for AI use and deployment, promote technical, legal, social and policy research, represent India in international dialogues on AI, and enforce AI principles and other policies in coordination with sectoral regulators.

At present, India has no holistic legislation on geospatial data regulation. However, there are close to 17 policies at the national level which are either in force or in draft[30]. Early signs are that these policies could be very restrictive. Almost any information with a hint of location can be classified as geospatial and hence sensitive. Previously, no acquisition or distribution/publication of such data could take place without the permission of the 'Security Vetting Authority'[31]. However, on 15 February 2021, the Government of India, issued new "Guidelines for acquiring and producing Geospatial Data and Geospatial Data Services including Maps", that aims at the liberalization of acquisition and pro-

26 https://ec.europa.eu/digital-single-market/en/public-sector-information-psi-directive-open-data-directive

27 https://www.europarl.europa.eu/doceo/document/TA-9-2021-0009_EN.html

28 https://ec.europa.eu/info/sites/info/files/proposal_for_a_regulation_on_a_single_market_for_digital_services.pdf

29 https://www.brookings.edu/research/6-developments-that-will-define-ai-governance-in-2021/

30 https://economictimes.indiatimes.com/news/economy/policy/geospatial-industry-leaders-seek-integrat-ed-geospatial-policy-under-pmo-led-agency/articleshow/72353172.cms?from=mdr>

31 Clause 3, The Geospatial Information Regulation Bill 2016

duction of geospatial data and geospatial data services including maps, through a process of Self-certification. This liberalization also removes any requirements for private players in the Indian market to seek approval and security clearances. Organizations are now free to process acquired geospatial data, build applications, and develop solutions and data products.3.7 Israel

The State of Israel is already considered a global hotspot for AI innovation. A 2018 report on AI innovation[32] lists Israel as the world leader in the number of AI companies with 2.5 AI companies per 1bn€ of GDP, i.e., five times the number for China, the EU and the USA. Israel's local high-tech talent is valued by the private sector, which is why tech giants have been establishing Israel-based AI research and development centers.

While Israel has no specific regulations or laws governing AI, according to the OECD website[33]the Israel Innovation Authority (IIA) has been working on such a legal framework. IIA also manages the Startup Nation initiative responsible for Israel's fast-growing ecosystem of more than 1000 active AI startups (~140 new AI startups every year) that have raised more than $10 billion since 2012 and 3.7 billion in 2019 alone.[34] The sectors driving AI innovation in Israel include healthcare, defense, and finance.

3.8 Qatar

In 2008, the State of Qatar announced the "Qatar National Vision 2030"[35] that outlined the country's plan to transition from an oil and gas-based economy to a knowledge-based one by 2030. By then Qatar had already started investing in developing a world-class technology infrastructure, and more importantly in building an exceptional higher education and research ecosystem with establishment of national research institutes, research funding programs and satellite campuses of renowned universities like Carnegie Mellon University, Northwestern University, Texas A&M University and Weill Cornell Medical College. These efforts have paid off well. The World Economic Forum (WEF)[36] recognized Qatar as a leader among MENA countries in two categories of vital importance for building an AI-based economy 1) Quality education systems, and 2) Ease of finding skilled employees.

In October 2018, the Qatar Center for Artificial Intelligence (QCAI) was launched by one of Qatar's national research institutes, Qatar Computing Research Institute (QCRI). Qatar was already planning to invest and make strides in this direction with the release of the National AI Strategy[37] in October 2019. This strategy was drafted and proposed by the QCAI.[38] Beyond these investments in AI research, Qatar's Ministry of Transport and Com-

32 https://ec.europa.eu/jrc/en/news/future-european-ai-being-written-now

33 https://economictimes.indiatimes.com/news/economy/policy/geospatial-industry-leaders-seek-integrated-geospatial-policy-under-pmo-led-agency/articleshow/72353172.cms?from=mdr

34 Clause 3, The Geospatial Information Regulation Bill 2016

35 https://dst.gov.in/sites/default/files/Final%20Approved%20Guidelines%20on%20Geospatial%20Data.pdf

36 http://www3.weforum.org/docs/WEF_EGW_FOJ_MENA.pdf

37 https://qcai.qcri.org/wp-content/uploads/2020/04/QCRI-Artificial-Intelligence-Strategy-2019-ENG.pdf

38 https://qcai.qcri.org/index.php/2019/02/07/qcai-releases-blueprint-of-national-ai-strategy-for-qatar/

munication also launched[39]a QR 6 billion (~US$ 1.65 billion) funding initiative, TASMU, to invest in enabling AI technologies to generate up to QR 40 billion (~US$ 11 billion) in economic activity.

Additionally, QCAI's parent entity QCRI has also signed collaboration agreements with multilateral agencies like UNDP, UNICEF, the World Bank, etc., to use AI for good. Specific examples of GeoAI technologies there include Qarta[40], QarSUMO[41] – a traffic simulator, automated map generation technologies in collaboration with MIT and other projects in partnership with Qatar Airways, and Boeing Research.

More recently, QCAI has conducted in-depth studies on how AI will impact the job market in Qatar[42], and is working towards the regulatory and policy framework for commercializing its AI research, and attracting other AI companies to incorporate in its special economic zones with independent legal jurisdictions from the country.

3.9 Saudi Arabia

In October 2017, Saudi Arabia made an unprecedented announcement that a robot Sofia[43] was granted citizenship of Saudi Arabia as a woman. While it is an interesting step, it is inconsistent with both several Saudi laws, and general legal frameworks around the world. It makes AI a subject of law and equal to a person. Regardless of the legal debate, the intention is clear that Saudi Arabia recognizes the importance of AI and is gearing up to realize AI's potential for the nation and its citizens.

The Saudi government established an agency called the "Saudi Data and Artificial Intelligence Authority" (SDAIA) on August 30, 2019. This agency's core mandate is "to drive and own the national data and AI agenda to help achieve Vision 2030's goals and our Kingdom's highest potential"[44].

The SDAIA plans to develop and execute national data and AI strategies and raise awareness about them and Saudi achievements in AI locally and globally. It has three subsidiary entities that oversee different aspects of executing its responsibilities:[45]

i. The National Data Management Office (NDMO), a regulatory body responsible for data and AI regulations, standards, and compliance.
ii. The National Information Center (NIC), that provides analytics and AI-based insights to the government and is responsible for maintaining the national data infrastructure.
iii. The National Center for Artificial Intelligence (NCAI) responsible for the advancement of AI innovations, providing AI strategic advice to the government, and promoting AI

39 https://www.motc.gov.qa/en/node/14067
40 https://qarta.io/
41 https://arxiv.org/abs/2010.03289
42 https://qcai.qcri.org/index.php/2020/11/20/impact-of-ai-on-qatars-job-market/
43 https://cic.org.sa/2017/10/saudi-arabia-is-first-country-in-the-world-to-grant-a-robot-citizenship/
44 https://sdaia.gov.sa/?Lang=en&page=SectionAbout#
45 https://futureoflife.org/ai-policy-saudi-arabia/

education.

Since its establishment, SDAIA has held several global AI hackathons, including one based on sports and one based on art. The agency plans to attract $20 billion in foreign and local investments by 2030 to achieve its objectives.

3.10 Singapore

At the request of the Singapore government, the Personal Data Protection Commission (PDPC) of Singapore started a consultation process in June 2018, and on 23 January 2019[46], released its first edition of the Model AI Governance Framework (Model Framework) for broader consultation, adoption and feedback. On 21 January 2020[47], the PDPC released the second edition of their Model Framework.

The document provides actionable and detailed guidance to the private sector for addressing ethical and governance issues during the deployment of AI solutions. To build and develop public understanding and trust in AI, the framework rests on two guiding principles 1) Decisions made by AI should be explainable, transparent and fair; and 2) AI systems should be human centric.

On the implementation front, the Framework defines four key areas of consideration for organizations to ensure adherence to the following guiding principles:

1. **Internal governance structures and measures:** The framework states that it is critical to define clear roles and responsibilities within the organization, set Standard Operating Procedures (SOPs) to monitor and manage risks, and provide appropriate training for staff to ensure responsible use of AI.
2. **Determination of the Level of Human involvement in AI-augmented Decision-making:** It underscores the importance of having an appropriate degree of human involvement in the use of AI, and to minimize the risk of harm to individuals.
3. **Operations management:** Highlights the goal of minimizing the bias in data and models and suggests using a risk-based approach to implement corrective measures and to consider issues of explainability, robustness and regular tuning when developing AI solutions.
4. **Stakeholder interaction and communication:** Ensuring that users are aware of AI policies and that they are articulated and communicated in ways that users can understand. Users should also be able to provide feedback.

Singapore's Model AI Governance Framework underscores the importance of having an appropriate degree of human involvement in the use of AI, and to minimize the risk of harm to individuals.

The Model Framework provides detailed use-cases and guidelines for the industry to implement these ideas. It is a good document for private sector entities everywhere. It also proposes that algorithmic audits be conducted wherever necessary to discover the actual workings of the algorithm in a solution. Such audits would have to be carried out at the request of the regulator with the jurisdiction over the relevant activity. It is ex-

46 https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4u7Mv

47 https://www.pdpc.gov.sg/-/media/Files/PDPC/PDF-Files/Resource-for-Organisation/AI/SGModelAIGov-Framework2.pdf

pected that conducting an algorithm audit would probably require engaging external experts, but also advises that analyzing risks, costs and benefits would be useful before proceeding with an algorithmic audit.

It also specifies that such audits should provide details on data accountability, explainable descriptions for the functioning of algorithms when there is doubt about the functionality, veracity or completeness of the information available. Sometimes existing information like product descriptions, system specifications, model training and selection records, data provenance records/trail, along with measures for removing bias in data are sufficient. It also highlights that algorithms are IP and have commercial value, therefore appropriate discretion and non-disclosure requirements should be satisfied by the auditors.

3.11 South Korea

In 2019, the South Korean Government released the National Strategy for Artificial Intelligence. This document lays down South Korea's vision for transforming domestic AI capabilities and promoting investment and innovation in the private sector.[48] The Ministry of Food and Drug Safety in South Korea has released several guidance documents on the use of AI and Big Data in medical devices.[49] These are the 'Guidelines for Evaluation of Clinical Efficacy of AI based Medical Devices'[50] and the 'Medical Device License Screening Guidelines (Guidelines for Complainants) (Amendment)'.[51] In 2016, the Korean Ministry of Science, ICT and Future Planning released the report "AI Information Industry Development Strategy".

South Korea has also enacted the Intelligent Robots Development and Distribution Promotion Act, 2008.[52] The Act defines an "intelligent robot" as a "mechanical device that perceives the external environment for itself, discerns circumstances, and moves voluntarily". It can be noted that unlike other sectoral AI laws seen in other jurisdictions, the South Korean law provides an extremely broad definition of the term "intelligent robot" and does not specifically define AI or ML or AI/ML enabled technologies/use-cases across sectors. It also provides that the Government shall develop five-year plans containing medium to long-term objectives for 'development and distribution of intelligent robots'. This law, among other things, also provides for procedures for quality certification of intelligent robots, and the creation of certifying authorities to carry out certification and standard setting. Further, the law creates special exemptions and regulatory/tax benefits for investment in the intelligent robot industry.

3.12 United Arab Emirates (UAE)

48 https://indiaai.gov.in/research-reports/national-strategy-for-artificial-intelligence-south-korea

49 https://asiaactual.com/blog/south-korea-software-guidance-big-data-ai-machine-learning/

50 http://www.nifds.go.kr/brd/m_15/view.do?seq=12744

51 http://www.nifds.go.kr/brd/m_15/view.do?seq=12743

52 Intelligent Robots Development and Distribution Promotion Act, 2008, a translated copy of the law is available at https://www.global-regulation.com/law/korea/644569/intellient-robots-development-and-distribution-promotion-act.html

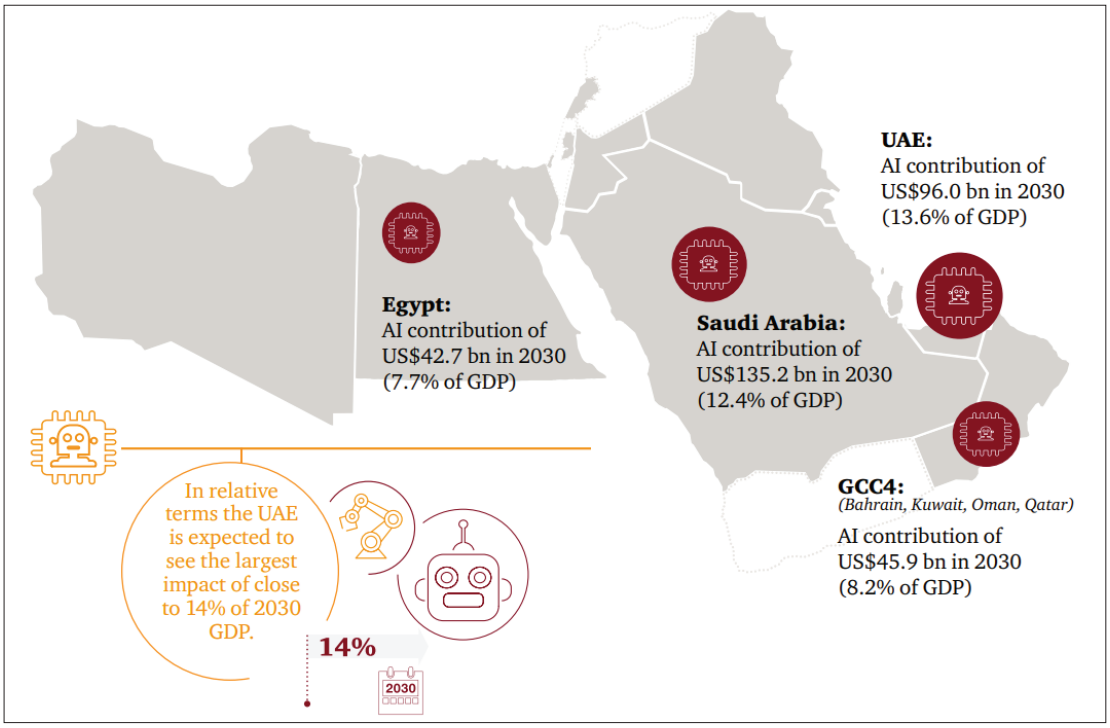


Figure 10: The PwC forecast for AI's contribution to the GDPs of Middle East nations (Source: PwC Report)

In the Middle East and Africa, key State players in AI are Israel and the Persian-Gulf countries, Saudi Arabia, UAE and Qatar. Iran and Egypt are the other two players with recognizable levels of current activity. A February 2018 report from the consulting firm PwC[53] forecasted that by 2030 AI could increase the GDP of Middle East's economy by 11% (or ~US$320 billion). While this report did not cover Israel or Iran, it predicted that the public sector will witness the highest impact from AI in the Middle East, including government services and education, thus implying more consumption of AI imports than exports of AI or AI-enabled products.

The PwC report says that the UAE would see the highest increase in GDP at 13.6% equivalent to US $96 billion. The report also recognized the efforts of the UAE government to ensure that AI is at the forefront of the government's strategic plans. It highlights their initiatives to support the development of AI and places the UAE in a strong position as one of the leaders for AI. Based on the publicly available information, UAE seems to be on track to ensure it capitalizes on the full potential of AI for its benefit. In March 2018, a month after the PwC report was released, the UAE AI Council[54] was launched with a cabinet minister leading the council, making it the first country to create an AI ministry. The objective was to become the world's most prepared country for AI. Since then, the Council has organized several high-profile events, announced a strategic bilateral part-

53 https://www.pwc.com/m1/en/publications/documents/economic-potential-ai-middle-east.pdf

54 https://ai.gov.ae/uae-ai-initiatives/

UK Government Guidance on AI in the public sector identifies six influencing factors for meeting user needs — data quality, fairness, accountability, privacy, explainability and transparency, and costs."

nership with India[55], released the national strategy for AI[56]and announced a national program for AI[57].

The primary objectives of UAE's push for AI are to modernize government services, reduce dependence on foreign labor, become an attractive destination for AI companies, and use AI effectively for national security. Emphasis is on utilizing AI technologies to remain competitive and effective.

In terms of laws or regulations, the only document published is the Abu Dhabi Department of Health's Policy on the Use of Artificial Intelligence in the Healthcare Sector. It presents an agile and evidence-based approach to regulation, allowing specific risks to be addressed quickly avoiding the unintended consequences that cannot be tackled with other laws of the country.

3.13 United Kingdom (UK)

There is no holistic regulation on AI. The House of Lords has suggested that blanket AI regulation for the UK will not be considered in the near future, and that the UK Information Commissioner's Office would be best placed to examine the impact on AI. Among the key policy developments surrounding AI regulations are the Industrial Strategy and AI Sector Deal, which sets out policy objectives for the UK to harness the potential of AI technology for society, and address the challenges posed.[58] The Deal will also support various sectors to "boost their productivity through artificial intelligence and data analytics technologies".

Over the past few years, various agencies of the UK Government have released white papers, and policy and strategy documents discussing the use and deployment of AI technology in the UK. In 2018, the UK House of Lords Select Committee on Artificial Intelligence released a detailed Report titled "AI in the UK: ready, willing and able?" The report discusses the potential for AI technologies across sectors, and examines technical details associated with design and development of AI —data, bias, investment, etc.

In January, 2020 the Office for Artificial Intelligence, the Department for Digital, Culture, Media and Sport, the Government Digital Service and the Department for Business, Energy and Industrial Strategy jointly published guidance on the use of AI in the Public Sector ("Guidance on AI in the public sector"). The Guidance is a holistic document to assist industry players in developing safe, accurate, and compliant AI systems for public use in the UK and identifies six factors which influence the use of AI for meeting user needs — data quality, fairness, accountability, privacy, explainability and transparency, and

55 https://www.arabianbusiness.com/technology/401650-uae-india-sign-deal-to-seek-20bn-artificial-intelligence-benefits

56 https://ai.gov.ae/wp-content/uploads/resources/UAE_National_Strategy_for_Artificial_Intelligence_2031.pdf

57 https://ai.gov.ae/wp-content/uploads/2020/02/AIGuide_EN_v1-online.pdf

58 https://www.gov.uk/government/publications/artificial-intelligence-sector-deal/ai-sector-deal https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/702810/180425_BEIS_AI_Sector_Deal__4_.pdf, at p.6.

costs. The UK Government has established three public bodies to implement the Deal and oversee AI innovation and development in the UK. These are: (i) the AI Council which consists of "independent members providing high-level leadership on implementing the AI Sector Deal", (ii) the Office for AI which shall "work with industry, academic and the third sector to coordinate and oversee the implementation of the UK's AI strategy", and (iii) the Centre for Data Ethics and Innovation which "identifies the measures needed to make sure the development of AI is safe, ethical, and innovative.

The UK has also established the Geospatial Commission (2018) which is an independent body coordinating geospatial activity and strategies in the public sector. The Commission is responsible for policy-making and standard setting in the geospatial sector. It has also conducted a study titled, "Future Technologies Review" which analyses the intersection of AI technology and geospatial datasets.

3.14 United States of America

AI regulation in the US has been gaining momentum, but there is no holistic federal law to regulate AI development and use right now. According to a few reports, in the 115th Congress, 39 bills on AI regulation or a related area were introduced.[59] In fact, as part of the annual defense bill for 2021, the US allocated $6 billion in additional funding for AI research, along with measures for increased federal level coordination of AI initiatives, and to promote explainability and accountability for AI systems. The bill mandates ethically and responsibly developed AI technology in government sourcing. One of the people involved in drafting the legislation, Sean Duggan a military legislative assistant said, "AI will only be as useful and accepted as people feel comfortable that it is a part of our everyday lives. If you can't explain that to someone on the street, a lot of its usage and future could be limited."[60]These policy proposals at the federal level are a significant step towards achieving accountability, safety and fairness in AI technologies but have also been criticized by some stakeholders and academics for being vague, non-inclusive, and relatively 'laissez-faire'.[61] Some national strategies and policy documents worth noting are —

59 https://www.loc.gov/law/help/artificial-intelligence/americas.php

60 https://www.fedscoop.com/congressional-staff-lay-possible-ai-agenda-next-term/

61 https://www.theverge.com/2020/1/7/21054653/america-us-ai-regulation-principles-federal-agencies-ostp-principles

the American 'AI Initiative' released in 2019[62], the National Institute of Standards and Technology's (NIST) Plan for Federal Engagement in Developing Technical Standards,[63] House Resolution 153— a bill to support the "development of guidelines for ethical development of artificial intelligence",[64] and restrictions on export of geospatial software recently issued by the US Bureau of Industry and Security (BIS).[65]Several proposals for regulating emerging services and technologies reliant on AI are being actively considered at the federal level. For instance, the Growing Artificial Intelligence Through Research Act of 2019,[66] the FUTURE of Artificial Intelligence Act of 2017,[67] and the Artificial Intelligence Initiative Act of 2019[68] seek to create institutional measures to promote and safeguard AI use. The Artificial Intelligence Initiative Act of 2019, for instance, shall set up a National Artificial Intelligence Research and Development Initiative. The bill also provides that the Office of Science and Technology Policy (OSTP) shall establish a National AI Advisory Committee, and several inter-agency committees on AI development. Further, the AI in Government Act of 2020 seeks to set up an "AI Centre of Excellence" to "advise and promote the efforts of the federal government in developing innovative uses of AI" for public benefit and "improve cohesion and competency" in AI use.

At the State level, law-making efforts have risen significantly in the following areas— regulation of autonomous vehicles, facial recognition technology, algorithmic accountability, and transparency/fairness in AI creation and use.

Aside from laws on regulation of autonomous vehicles, US lawmakers have been actively advocating for greater accountability and transparency of AI algorithms. The House and Senate Bill on Algorithmic Accountability is a significant step in this direction. Introduced in 2019, this Bill seeks to ensure that covered entities[69] conduct "assessments of high-risk systems that involve personal information or make automated decisions". The legal obligations outlined in the Bill would be applicable to a range of sectors and the Bill specifically, is aimed at larger corporations or data brokers which meet the threshold value of consumers and revenue as provided in the text.[70] A significant and focused legislative development in the specific context of geospatial technology is the adoption of 'export licensing requirements' by the US Bureau of Industry and Security (BIS) in 2020. These requirements have been adopted by way of amendments to the Export Administration Regulations. According to these, certain software such as "geospatial imagery software" which is "specially designed for training a Deep Convolutional Neural Network

62 https://www.whitehouse.gov/wp-content/uploads/2020/02/American-AI-Initiative-One-Year-Annual-Report.pdf

63 https://www.nist.gov/system/files/documents/2019/08/10/ai_standards_fedengagement_plan_9aug2019.pdf

64 https://www.congress.gov/bill/116th-congress/house-resolution/153/text

65 https://www.federalregister.gov/documents/2020/01/06/2019-27649/addition-of-software-specially-designed-to-automate-the-analysis-of-geospatial-imagery-to-the-export

66 https://www.congress.gov/bill/116th-congress/house-bill/2202

67 https://www.congress.gov/bill/115th-congress/house-bill/4625

68 https://www.congress.gov/bill/116th-congress/senate-bill/1558

69 https://www.congress.gov/bill/116th-congress/house-bill/2231/text

70 https://www.theverge.com/2019/4/10/18304960/congress-algorithmic-accountability-act-wyden-clarke-booker-bill-introduced-house-senate

to automate the analysis of geospatial imagery and point cloud" cannot be exported outside the US (with the exception of Canada) without an export license.[71]

71 https://www.williamsmullen.com/news/commerce-adopts-export-controls-artificial-intelligence-software-geospacial-imagery-controls

Recommendations

The purpose of AI policies is to maximize the benefits of AI for society as whole, while minimizing its potential risks. With 36 countries and almost all G20 countries having National AI strategies, the case can be made that governments around the world recognize the potential and inevitability of the AI revolution. They understand well that AI provides a set of very powerful tools to compete in our fast-changing world.

While it may be easier to blindly regulate technologies in the early stages of their development, restrictive policies can deter innovation and progress. The pace of technology-driven change can be so fast that restrictive policies soon become obsolete. Laws are path dependent, and the first set of policies will likely shape the limits of future policy options and corrections. Therefore, it is important to get legislation and regulations directionally right from the beginning. We should regulate only when necessary and then also ensure that we have an agile form of governance for AI. This is important because technology developments also lead to evolution in what is both acceptable and enforceable.

One scenario that may be useful in order to enable the responsible adoption of GeoAI offerings is for industry, government and NGOs to monitor developments and regularly convene fora among stakeholders to map issues and gaps. This allows for a staged approach to identify concerns that can only be addressed through regulations. Such groups should also classify AI use-cases by the risk of potential harm to individuals and society. Big firms are aware that their actions can affect a larger number of users and hence the risk of potential harm is higher. Therefore, they prefer a predictable policy environment and guidelines. Fast growing smaller firms that sometimes start by innovating under uncertain policy environments would also benefit as they can assess their future responsibilities using such a framework and take timely actions.

The idea is to not restrict innovation, and hence we could start by trusting the innovators first. If any abuses of the existing regulations are observed, then the stage-gate[72] approach would involve a first attempt to ensure no existing laws have been violated. If that's not clear, then the next stage involves identifying technologically feasible solutions. Similarly, later stages could include corporate self-governance and soft law[73] (i.e. non-binding guidance) based approaches. Legislating to solve the problem should be a last resort as laws are very difficult to update.

72 https://futureoflife.org/2019/11/15/machine-ethics-and-ai-governance-with-wendell-wallach/

73 Soft law refers to frameworks that "set forth substantive expectations but are not directly enforceable by government, and include approaches such as professional guidelines, private standards, codes of conduct, and best practices." Source: https://www.brookings.edu/research/soft-law-as-a-complement-to-ai-regulation/

4.1 Data-Related Recommendations to Promote GeoAI

Geospatial data plays a fundamental role in today's world because it provides spatial context for other types of data. Since 2008, when the USGS adopted a free and open Landsat data policy, the use of Earth observation data has been growing rapidly. The open data policies of the US and other countries have benefited many segments of society including the geospatial industry which has seen an accelerated growth in the past decade.

The value of geospatial data comes from insights that it delivers into the use of physical spaces, and/or the state of our natural environment. Geospatial data is increasingly becoming higher quality, timelier, and more abundant while the costs per unit of data are decreasing.

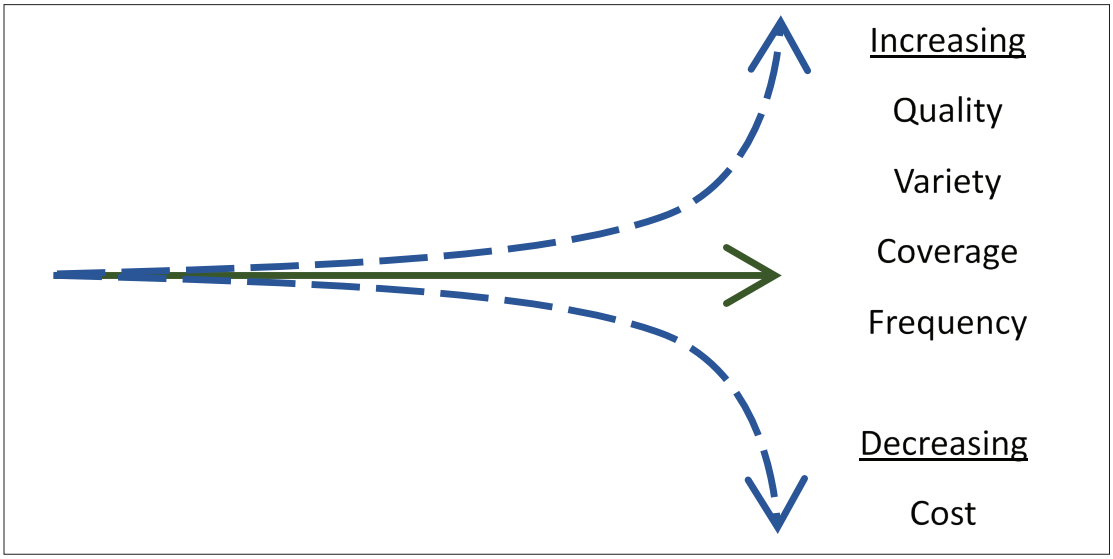


Figure 11: Trends in Geospatial data (Source: Graphic adapted from Planet Labs)

As data is the fuel for growing an AI economy, we sought out the perspectives of study participants specifically on data and how it could be used for increasing innovation in geospatial technologies as well as ensuring the benefits of AI reach to everyone in society. This also requires building and nurturing vibrant startup ecosystems for geospatial technologies.

Following are the key ideas and observations that emerged from our discussions and were also the consensus of the experts interviewed:

i. **Increased access to government data:** There was unanimous agreement on continuously working towards making more government owned data accessible to everyone. Everyone felt that governments sharing data freely is critical for realizing the benefits of GeoAI.
ii. **Metadata standards and labeling:** As raw data itself is of not much use for almost all AI techniques, ensuring that there are universally accepted, clear and comprehensive metadata standards is critical for the success of GeoAI. Ensuring that metadata labeling is done properly and always is equally critical.

iii. **Test datasets and benchmarks:** Most respondents agreed that there is a strong need for creating a body of labeled geospatial data (e.g., commercial satellite imagery) for training, testing and benchmarking models. Performance benchmark tests on such datasets will allow us to compare algorithms and their results. Experts also recognized the important contributions of initiatives like BigEarthNet[74], SpaceNet[75], Impact Observatory's Dynamic World Project[76] and Radiant Earth[77].

iv. **Incentivizing private data access:** While a significant amount of geospatial data is freely available through Open Data programs of governments or non-profits, much data is proprietary and resides in silos. This results in suboptimal utilization of data as innovative startups, researchers or others cannot easily access such data. Governments should consider incentivizing organizations for sharing of such data at reasonable costs. This could be done through promoting data trusts/exchanges, and new rules making it easier for corporations to share such data while getting the rightful benefits. For example, soft law approaches like Fair, Reasonable, and Non-Discriminatory (FRAND)[78] for patents could be adopted for such proprietary data. American IP Law Association[79] has recommended USPTO[80] to consider creating mechanisms to facilitate sharing of data from large companies with the small ones and avoid further monopolization.

v. **Shared AI Models:** Some participants felt strongly that sharing algorithms/models openly is vital for the benefit of all. It was highlighted that a growing number of AI driven companies have been putting their models and algorithms under open source because the business models for AI benefit from being open to new ideas from everywhere, and open sourcing is a great way to crowdsource the best ideas from everywhere.

vi. **Traceability and veracity of data:** AI systems in use make predictions based on what they have learned from training datasets. Therefore, it is very important to ensure data is trustworthy and not modified. Being able to track the source of data or any modifications in it along the value chain makes it trustworthy. Reliable solutions to this problem based on either technology or cooperative agreements (e.g. embedding digital signatures at every stage) would also increase the likelihood of data-sharing among corporations.

vii. **Right to self-determination for privacy:** Geospatial data can be analyzed to derive personally identifiable information (PII). Therefore, the US and many other countries, classify geospatial data related to people as "Sensitive"[81]. Also, the debate around personal data ownership has been gaining momentum, as proponents say individuals should be the owners of their data. Regardless, governments and people everywhere recognize that data privacy is a very important concern. Based on the responses of our study participants, we can recommend "Right to self-determination" as a policy

74 http://bigearth.net/

75 https://spacenetchallenge.github.io/

76 https://www.impactobservatory.com/

77 https://www.radiant.earth/about/

78 https://www.upcounsel.com/frand-licensing

79 https://www.aipla.org/docs/default-source/advocacy/documents/aiplacomments_uspto_rfc_patentingai2019nov08.pdf

80 https://www.uspto.gov/sites/default/files/documents/USPTO_AI-Report_2020-10-07.pdf

81 https://www.uspto.gov/sites/default/files/documents/USPTO_AI-Report_2020-10-07.pdf

position for WGIC. This position is in alignment with respective laws in the EU and California.

viii. **Multilateral data exchanges and standards:** Promotion of universal standards on data exchanges among countries by facilitating or promoting such initiatives.

4.2 AI Policy Principles for Self-Governance in the Geospatial Industry

The geospatial industry could adopt a set of principles or guidelines for GeoAI governance. It is a common idea as more than 150 such guideline documents (for AI and data related governance) have been submitted by various organizations and groups at Algo-

rithm Watch[82]. At the country level, the Singapore government has released a general-purpose (or application agnostic) framework for AI governance[83] document that forms a good basis for a soft law approach.

Earlier this year, Harvard University's Berkman Klein Center analyzed 36 prominent AI governance frameworks and published their findings[84]. They found that there was a growing consensus around eight key thematic trends in AI governance: 1) privacy, 2) accountability, 3) safety and security, 4) transparency and explainability, 5) fairness and non-discrimination, 6) human control of technology, 7) professional responsibility, and 8) promotion of human values.

Considering all the information reviewed and the interviews conducted with experts from the geospatial community, we believe the geospatial industry should consider the following policy guidelines:

i. Ensure that industry's policy positions are in alignment with the growing consensus around the ethics and governance of AI technologies globally.
ii. Geospatial business organizations should be encouraged to lead by example, and in good faith build norms for ethical use of AI so that customers, citizens, and policy makers have strong reasons to trust the geospatial industry. For example, companies should have an internal framework/process and function that can review and advise on potential breaches of general ethical principles in the activities being undertaken.
iii. Underscore that AI technologies are changing rapidly, and in turn, recognize that could change the definition of what is private, sensitive information or a State secret. Therefore, policies should be adaptive to the state of technology and stay cognizant of the new normal or enforceability of the regulations.
iv. The industry should work towards creating and maintaining a classification of use-cases or application areas by the risk of potential harm. Considering the dynamic nature of the AI domain and the rapid pace of change, such a taxonomy would need to be regularly (if not continuously) updated. It could be used effectively by government agencies to calibrate regulatory/policy restrictions. Whenever introduced, regulations should also clearly articulate what final outcomes are out of bounds.
v. Industry bodies should collaborate to create the appropriate set of tests and checklists for geospatial industry that could help companies self-audit or become a standard for third party AI auditors.
vi. Access and availability of good training data, benchmarks and tests are vital for the proliferation of AI technologies.
vii. To promote innovation, the geospatial industry should establish protocols that enable it to trust innovators and promote regulatory controls only where potential abuses are noticed.

82 https://inventory.algorithmwatch.org/

83 https://www.pdpc.gov.sg/-/media/files/pdpc/pdf-files/resource-for-organisation/ai/sgmodelaigovframework2.pdf

84 https://papers.ssrn.com/sol3/Delivery.cfm/SSRN_ID3518482_code727672.pdf?abstractid=3518482&mirid=1

Appendices

Appendix I: Learnings from Managing GeoAI Projects

As we wanted to tap into the existing accumulated knowledge and experiences of WGIC members and other opinion leaders, from academia, government and the geospatial industry, we also asked about their experiences working on real-world GeoAI projects within their organizations. Here are some of the noteworthy points that emerged from these discussions:

i. General expectations from AI/ML projects are sometimes unreasonably high and the results often falls short of both internal and external expectations;
ii. It is important to have greater repeatability and predictability of the factors that go into successful GeoAI projects;
iii. Solutions developed for one part of the world do not always necessarily translate to other parts of the world because there is a lot of heterogeneity in spatial and temporal data globally;
iv. Several respondents identified early successes in projects involving image processing and computer vision and highlighted the importance of framing the problems correctly to achieve the desired results;
v. Most respondents highlighted the importance of selecting the right data and framework for a specific problem, always staying up-to-date with developments in the field, setting measurable goals and validating and testing technologies in advance of implementation;
vi. When asked about common pitfalls, several respondents warned against relying on poor, insufficient and non-curated data, biases introduced during ML training and relying on data scientists with little or no geospatial backgrounds;
vii. AI is not consistent, and making it robust requires both large amounts of data, accounting for possible variations of all kinds and improvements in algorithms. Models working on test data often do not work the same way on real world data; and
viii. As is the nature of innovation, most AI/ML projects would fail to reach a successful commercialization stage (20% success rate is good). Therefore, these pilots and proof-of-concept projects should be managed accordingly, and the resource/time allocation should be done in a stage-gate or milestone-based approach.

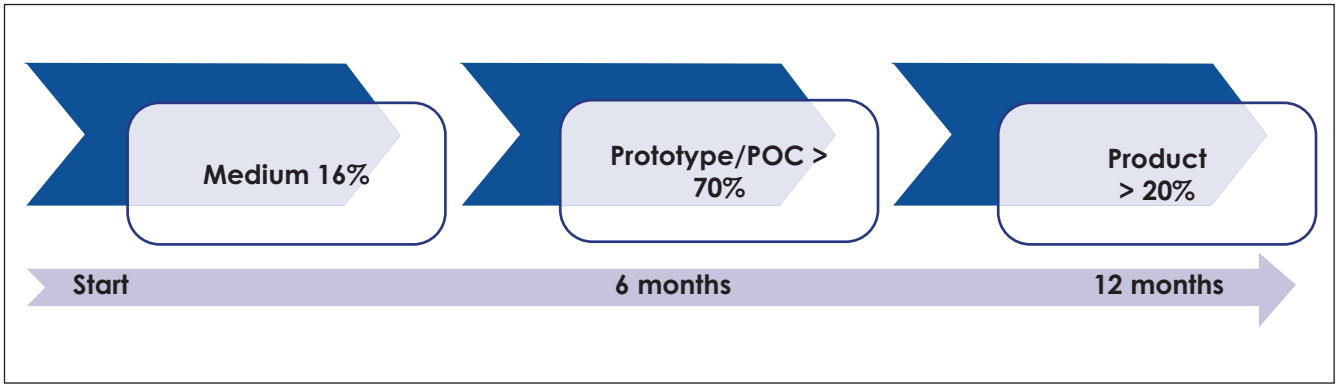


Figure 12: Success Rates and Average Timeline for AI/ML Projects in Geospatial

Appendix II: Research Problems of Interest to the Geospatial Industry

The participants of our study stressed that having more academic research for solving the problems from the geospatial industry is required. The specific areas requiring more GeoAI research are:

i. Image acquisition with automated label annotation;
ii. Pre-processing of satellite imagery on the edge and on ground;
iii. Edge computing for point cloud data cleaning and calibration;
iv. Solutions for curation and quality management of geospatial data;
v. Unsupervised learning for computer vision tasks and automated labeling;
vi. Use of high dimensional (HD) mapping simulations, e.g., digital twins of cities;
vii. Identifying more attributes and features of objects detected;
viii. Multispectral imagery analysis to capitalize on the value potential of satellite data;
ix. Making GeoAI algorithms explainable and hence more accountable/trustable;
x. Multimodal data analysis that capitalizes on all kinds of data sources;
xi. Time series analysis of geospatial data;
xii. Combining low-resolution satellite tasking with high-resolution high-frequency satellite data for solving customer problems; and
xiii. Ensuring results of GeoAI tools are ethical and unbiased.

Today's tech users expect simplicity and frictionless user-interactions with technology. Similarly, even with geospatial analyses, users expect to get an answer directly and easily.

It would be advantageous to combine human and physical geography data to analyze information at different scales. Adding other data from sensors or social media can further enhance its value, and is fortunately already being considered.

As mentioned earlier, an important difference between traditional AI/ML applications and GeoAI applications is the volume of data, with the latter being both extensive and multi-scale. Unfortunately, this data is often poorly structured and hence difficult to process.

Most participants felt that any new techniques developed specifically for solving challenges with geospatial data, will also benefit traditional AI/ML applications in domains like computer vision and natural language processing. Currently geospatial analysis allows traditional AI/ML applications to be used and operated by minimizing errors, e.g., cross-referencing with point of sale (POS) location data to double check transaction data decreasing fraud in erroneous transactions.

AI enabled automation is also replacing highly repetitive tasks. Imagine if using geospatial data were widely accepted as a proven workflow, it will then it would most certainly reduce processing times and increase automation while ensuring completeness. Another domain where GeoAI solutions can be adopted is to enhance the analysis of medical images. Similarly, such techniques will also enable physical-to -digital transformations, improve precision via automation and use of sensors. At the end of the day, the ability to manage unstructured data workflows by GeoAI (relative to other techniques) will be useful for other AI applications.

Appendix III: Intellectual Property Issues Related to AI

One of the issues that resonated with most of the participants was the intellectual property (IP) regime for AI/ML. This is understandable as the field of AI, and GeoAI particularly, have unique aspects that make IP a common concern.

Following are the issues around IP rights that have been identified over the course of this study:

i. **Can an AI algorithm be an inventor?** As the state of AI is improving daily, algorithms' contribution in identifying novel ideas could be crucial. As such the US Patents and Trademarks Office (USPTO)[85], the UK Intellectual Property Organization[86] and the European Patent Office (EPO)[87] have all rejected the idea of AI ownership because their definition of an inventor must be a human being.
ii. **Reviewing AI patents is very different:** It is not clear how an AI patent should be reviewed. How can Patent Examiners determine non-obviousness/novelty? Patents granted are expected to have clearly outlined the "inventive steps".[88] How can anyone determine the applicability of this clause for a black-box deep learning algorithm? Further, the question arises whether mandating explainability of algorithms be helpful?
iii. **Disclosure requirements:** Often AI algorithms evolve their internal decision-making criteria (i.e., weights) based on new data used for training. Does this mean that the training data should also be disclosed,[89] or should there be means to continuously update the disclosure.
iv. **Open and publicly available data:** With large amounts of geospatial data being generated and made public by governments and even consumer applications, it is tricky to determine "fair-use" and modifications[90]. Open data sources want to ensure that people use only the authentic copy in order to maintain integrity of systems. At the same time, large corporations allow teaching and research as fair-use but prohibit the use of any of their public data to train AI algorithms. Training students is fine, but training a tool is not, even when it is for a transformative[91] use. As per US law, raw data are facts and not original works of authorship[92], hence data cannot be copyrighted unless the way it has been presented and structured is unique and valuable.
v. **New regulatory regime for data rights:** Should there be a new regime for data rights protections that can allow data siloed inside the large corporations to become accessible for other organizations at reasonable cost and safely.[93] Most non-ICT organizations

85 https://www.theverge.com/2020/4/29/21241251/artificial-intelligence-inventor-united-states-patent-trademark-office-intellectual-property

86 https://www.ipo.gov.uk/p-challenge-decision-results/o74119.pdf

87 https://www.epo.org/news-events/news/2020/20200128.html

88 https://www.aipla.org/docs/defattult-source/advocacy/documents/aiplacomments_uspto_rfc_patentingai2019nov08.pdf

89 https://www.wipo.int/export/sites/www/about-ip/en/artificial_intelligence/conversation_ip_ai/pdf/igo_epo.pdf

90 http://www.ip-watch.org/2017/08/23/dilemma-fair-use-expressive-machine-learning-interview-ben-sobel/

91 https://www.dwt.com/blogs/artificial-intelligence-law-advisor/2018/04/artificial-intelligence-fair-use-and-using-ai-to-c

92 https://www.natlawreview.com/article/us-copyright-protections-market-data

93 https://www.aipla.org/docs/default-source/advocacy/documents/aiplacomments_uspto_rfc_patentingai2019nov08.pdf

have a lot of data that gets collected, but the capacity to analyze it is often lacking. Organizations could also benefit from a data policy regime that enables them to monetize the data they already have.

vi. **Trained Model rights:** Should there be a new category of IP rights for trained models that could be traded?[94] Model outputs can differ a lot depending on the initialization parameters, and they tend to work on data with a specific structure only. At the same time, many big tech firms with large AI teams have been putting their AI libraries in the open source. In such a landscape, a case can be made for a new kind of IP right for Trained Models as most of the intellectual effort would have gone in the training and tuning of such a model built on open-source libraries.

Can an AI algorithm be an inventor? As the state of AI is improving daily, algorithms' contribution in identifying novel ideas could be crucial.

94 https://ipo.org/wp-content/uploads/2020/11/SG-model-rights-committee-paper-pub.pdf

Appendix IV: How to Build Ethical and Trustworthy AI Systems

As defining accountability for decisions made with the help of AI systems, is a big concern due to the potential harm it could cause, here we present an approach to tackle this issue within organizations planning to use AI. This approach aligns well with general good practices for any responsible business/organization. Shown below are steps that could be considered by organizations to ensure that AI systems or offerings are trustworthy:

Identifying all stakeholders

This is often part of the product conception and design phase as well. Knowing all the stakeholders for a product/offering is a critical first step. This includes customers, intermediaries, the organization itself, and regulatory and law enforcement bodies too.

Defining Ethical Principles

Outlining scenarios and making rules for those scenarios is neither possible nor advisable. Therefore, identifying key principles to follow for conception, design and launch of AI offerings is critical. These should include:

Beneficial to society and cause no harm: Being part of the society, organizations are expected to work towards society's betterment and will be held responsible for any harm caused.

Clear accountability: Leaders within the organization should be assigned accountability for the acts and omissions of AI systems operating under their watch. This will ensure compliance with any existing laws, e.g., privacy, discrimination, IP rights, criminal use, dual-use possibilities, etc.

Transparency/Explainability: Assigning accountability is not possible without being able to explain why, and how, a decision was made – whether it is an automated decision made by an AI system, or a decision taken by a human with assistance from an AI system. Therefore, it is imperative to ensure the use of AI and the data involved is transparent, and that the decision outcomes of the AI system are explainable.

Reliability: Ensuring that AI systems are reliable implies providing unbiased results in a repeatable manner for similar inputs so that all stakeholders feel confident trusting it. It is important to gain the trust of customers so that AI systems do not provide unreliable outputs when encountering perturbations/errors in data inputs or other conditions.

Responsibility

In accordance with the principles adopted, key individuals responsible for any breach of ethical legal responsibilities associated with any project should be identified. As with most organizations, the ultimate responsibility for success or failure of any such project lies with the top leadership of the organization.

Organizations should create a Responsible AI Review committee to ensure development, sales and deployment of AI offerings take place in accordance with the ethical principles adopted by the organization. Examples of things to consider include, ensuring explaina-

bility in high-risk use-cases, compliance to discrimination laws, avoiding perceived mal-intent situations that can hurt their brand, and making a well-intentioned effort to not sell GeoAI insights/offerings to rogue actors who could use it for criminal purposes, e.g., organizations with potential terrorist ties.

Decision Making
It is important to clearly outline how decision-making occurs in a business workflow involving an AI system. It must be defined what, and what does not, get decided or recommended by the AI system, and how a manager will be using the system's outputs. Knowing the clear purpose of AI system will help developers build it accordingly.

Determine Risks
From the conceptualization stage itself, the severity and risks of potential harm in using an AI system must be thought through. While it is not a one-time exercise and is apt to be repeated whenever new information becomes available, it is a good ritual before starting AI product development. It is quite likely that such a practice will become part of law or soft-law recommendations from the governments because this will allow for risk-based categorization and regulation of AI systems.

Assess Bias in Data and Models
Checking for any bias in data and models is a common requirement being considered in many legislative efforts around the world for regulating AI. Therefore, preemptively instilling such a practice in the development process of AI offerings would be a great "good faith" endeavor from organizations.

Stakeholder Feedback
Gathering feedback from different stakeholders to refine product or service offerings is a good business practice. In the case of AI, it will help ensure that organizations avoid any unintended consequences of their offerings including potential legal liabilities.

About WGIC

The World Geospatial Industry Council (WGIC) is a registered Not-for-Profit trade association of commercial geospatial companies representing the geospatial ecosystem's entire value chain. WGIC enhances the geospatial industry's role and strengthens its contributions to the global economy and society. WGIC facilitates the exchange of knowledge within the geospatial industry and creates more significant business opportunities for the stakeholders through partnerships and collaborations in thematic areas of global significance.

For more information, please visit www.wgicouncil.org.
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