United States Geospatial
Intelligence Foundation (USGIF)
September 2021

The State of Artificial Intelligence and Machine Learning (AI/ML) in the GEOINT Community and Beyond

ABSTRACT:
This USGIF whitepaper is intended for government and industry leaders involved in the defense, intelligence, and specifically the Geospatial-Intelligence ("GEOINT") community with an interest in AI/ML. The paper will provide an overview in AI/ML capabilities currently in China, Russia, and other actors. The paper will highlight several problem sets today in GEOINT, namely current capability gaps in the GEOINT community, with discussions on US policy, leadership, and culture around AI/ML. The paper will provide ideas on how to address the AI/ML gap with workforce training, leadership backing, and culture shifts. Finally, the paper concludes with several GEOINT-based AI/ML use cases.

1.0 Executive Summary

"DoD does not have an innovation problem; it has an innovation adoption problem." This comment from the Defense Innovation Board in 2018 holds true today. There are numerous groups in the GEOINT community attempting to perform AI/ML operations. There are innovative people and programs, but we feel there is not a solid AI/ML adoption plan in place. The goal of this paper is to show there can be a path forward for AI/ML adoption and success. We suggest the GEOINT community follow these below recommendations to train the GEOINT workforce in modern practices, bring AI/ML into the mainstream, and provide a multi- and hybrid-cloud approach that supports the workforce in the most efficient way possible.

2.0 Recommendations

We recommend the following for the United States' GEOINT community to be the world leader in AI/ML.

1. Ensure executive leadership uses a comprehensive communications plan to highlight support for AI/ML modernization of the processes and technologies in GEOINT workflows, analytic tradecraft, and analyst training.
2. Create an unclassified AI/ML training pipeline for GEOINT analysts and staff that focuses on how to find and load imagery, create and manage computer vision models, and assess model performance.
3. Provide an unclassified (Impact Level 2) AI/ML testbed environment that is stored in a hybrid cloud environment - both on premises and in cloud. Today, it is a challenge for analysts to find unclassified imagery, load that content into a development testbed, add image classifiers, and train and test models. With the advent of modern technologies such as automated image labeling, power chips such as Tensor Processing Units (TPU), and major cloud providers, it is rather simple to create and maintain AI/ML testbeds. Additionally, ensure there is a consistent process for loading unclassified imagery into the application, allowing for analysts to have all downstream rights to derivative products, and ensuring the app can grow to a planet-wide scale.
4. Establish communal benchmark data sets, metadata, and performance metrics for comparative assessment of AI/ML model performance.
5. Create instructional media for all facets of these recommendations, and place this content on the NGA YouTube page in consistent "What is…?" video formats for the widest possible dissemination - from what is computer vision, how to select and load imagery for training, how to create image classifiers, and how to train and test individual and/or team AI/ML models. This could show NGA as the leader in teaching AI/ML for its own analysts as well as future employees who may be in school today.
6. Have analysts who are proficient in AI/ML provide "success story" content to demystify the complexity of AI/ML. Various groups highlighted within this white paper working group created country-wide scale Computer Vision examples in a matter of hours and with not one line of code written.
7. Review the industry examples in Section 5 as possibilities for designing solutions or initial expansions into AI/ML, since these have been proven already. In industry example one, Maxar describes a technique using NVIDIA software and Graphics Processing Units (GPUs) to rapidly generate training data using synthetic 3D models with real imagery when traditional examples might be limited or time consuming to produce. In example two, Clarifai worked to determine the feasibility of using synthetic data to train models to detect objects for which very limited images exist.. In example three, the Naval Research Lab (NRL) performed anomaly detection in hyperspectral imagery. In example four, Google created an automated capability with custom imagery classifiers to build a computer vision AI/ML model for Humanitarian Assistance/Disaster Response to save considerable time when reviewing post-event imagery.

3.0 National Approaches to Investing in AI/ML

The March 2021 National Security Commission on Artificial Intelligence Full Report summarizes the state of AI/ML in the United States bluntly, "America is not prepared to defend or compete in the AI era. This is the tough reality we must face. And it is this reality that demands comprehensive, whole-of-nation action." If the GEOINT community continues on its "as is" plan for AI training, AI operations, an incoherent AI strategy, and the lack of supporting infrastructure, we fear China and other near-peer competitors will dominate AI and threaten our national security and cyber security.

The GEOINT community needs a more defined AI strategy to:

- Clearly articulate its primary computer vision (CV) strategy
- Determine how to train the current workforce
- Hire AI expertise
- Determine how CV is used in the GEOINT analytic workflow processes
- Employ modern cloud and AI technologies at all classification levels in order to catch up to foreign competition and become the world leader in application of CV to GEOINT.

US adversaries are approaching investments in AI/ML strategically. There is a massive gap between Chinese government investment in AI and US government investment, and this increased investment has led to China catching up and surpassing the US in AI capabilities. China is serious about AI, and is doing everything it can to establish itself as the world leader in not only AI, but computer vision (CV). For GEOINT, CV is critical in automating imagery and Full Motion Video (FMV) analysis; it is also a key technology in military drones and autonomous systems. Chinese CV experts hone their tradecraft in universities, and their pipeline towards supporting the military is unquestioned. By contrast, the US GEOINT community does not yet have a defined and dedicated technology infrastructure to support CV, does not have a huge, unclassified data set on which to train CV models, does not have a centralized and vetted library of CV capabilities (e.g. object detectors for T-14 Armata tank, J-20 fighter, etc.), and does not have a robust network of talent from industry, academia, and the government collaborating on advancing US CV capabilities. While Russia is not investing as much as China, they have demonstrated a commitment to developing artificial intelligence technology that may allow them to dominate specific sectors in the future. Additionally, use of AI and ML by non-state actors such as insurgent groups, drug cartels, criminal groups, and arms dealers will expand as commercial capabilities proliferate and reach lower price points, further complicating threat scenarios as governments and security forces seek to counter these threats.

4.0 AI/ML Baseline

The first step to address adversary AI/ML GEOINT threats on the road to global leadership is to understand the baseline of existing challenges facing the GEOINT community's advancement in these key capabilities. A number of these challenges exist in the realm of policy. Of particular interest are concerns related to ethics, privacy, and intellectual property rights associated with the development of new AI/ML capabilities. Without addressing these concerns up front, the GEOINT community runs the risk of new technology development outpacing our ability to understand the potential unintended consequences that may be driven by that technology.

4.1 Policy Challenges

The US Government's commitment to upholding the privacy and civil liberties of its citizens contrasts starkly with the policies of our adversaries. China provides a clear example. Rather than limiting data collected on its citizens, it sponsors many state programs, such as The Social Score, aimed at creating comprehensive views of each citizen's behavior. This wealth of data provides China with a head start when training and fielding new algorithms. To help combat this advantage, the US Government, and the members of the GEOINT community, must band together to advance progress while maintaining strong ethical considerations. We believe that special focus should be placed on a few key areas.

4.2 Data Privacy

Enforcing geospatial data privacy standards that apply to Government agencies alone is insufficient to address the emerging data privacy needs associated with AI/ML. Both state and non-state actors can leverage US persons' locational data to build new models. Unfettered access to these data sources opens the door to microtargeting, the phenomenon of singling out individuals with a precision never seen before. To combat these emerging threats, the US Government needs to implement strong data privacy protections to reduce the risk to its citizens.

4.3 Leadership Challenges

In addition to the policy challenges faced by the US Government in implementing AI solutions, there are fundamental challenges the nation must face to be the global leader in AI/ML. These challenges include improving AI/ML literacy, investing in diverse pathways for research and innovation, and sustaining a national AI/ML leadership culture focused on growing the next generation of AI/ML leaders. In our view, leading the world in AI/ML capabilities goes beyond cutting edge research and extends to the real-world impacts that newly developed AI/ML capabilities make in our lives – both within and without the GEOINT community. Leading the world in AI/ML results in key outcomes that make our nation more competitive.

4.4 Sustaining AI/ML Leadership

We believe that the United States GEOINT community controls its own destiny in continuing to maintain global leadership in the field of AI/ML. The US boasts the highest number of premier AI/ML research institutions, private companies, and Government research entities, providing a strong foundation for continued growth and investment. We see three key areas that as essential to build on this existing momentum.

As a Nation, and especially in the GEOINT community, the success of AI depends on a common baseline of understanding with regards to what AI/ML is, how it will impact our personal and professional lives, and how to separate fact from fiction. Often, references to AI in popular culture (in films such as The Terminator or 2001: A Space Odyssey) present AI as something to be feared. Many AI-centered stories in the press focus on how AI will obviate workers' jobs by automating them out of existence. These external influences increase distrust of AI technology, reducing adoption and slowing the impact that these new technologies can bring.

Continued AI/ML leadership requires a focused, diverse strategy for investing in AI. As China continues to make large investments in AI, the Nation must find ways to make similar investments to maintain its competitive edge. We agree with the National Security Commission on Artificial Intelligence's recommendation of increasing non-Defense AI/ML spending to $32 billion per year by 2026--and we believe the GEOINT community is well positioned to do so, given the myriad commercial applications for GEOINT. We also agree with their recommendation to strengthen commercial competitiveness by investing in a network of regional innovation clusters, such as the geospatial ecosystem developing in St. Louis, Missouri.

5.0 AI/ML Solution Components and Real-World Industry Examples

Adopting AI/ML capabilities for GEOINT missions is a complex task. There is not a "silver bullet" or a single solution that fits all. An effective and practical approach is developing a tailor-made solution for a given GEOINT mission based on best practices and industry examples. When designing an AI/ML solution, the key factors for the GEOINT Community to consider include data strategy, data workforce, data engineering, and data science. Selecting the right components for the solution and integrating all the components together can determine operational success.

The data science component of an AI/ML solution seeks to identify patterns in large data, learn from past behaviors, and predict new outcomes. Implementing it typically requires (1) computing technologies, (2) conditioned data, and (3) modeling algorithms. Computing technologies (such as CPU, GPU, TPU, and edge computing) process data manipulations and execute ML model algorithms. Because AI/ML solutions with big data are process intensive, sufficient computing power and infrastructure are necessary, and the means to minimize the latency between the data storage and computation can also be considered. In Section 5.1, the Industry Example #1 highlights how GPU can be leveraged to accelerate the processing.

Conditioned data are used to train and test AI/ML models. Large volume and high quality data yields better predicting AI/ML models. But often, such data do not exist, because there may only be a large volume of poor quality data, a small volume of high quality data, or neither. The first two Industry Examples below resolve the problem of lacking large, quality data with synthetic data generation.

Model algorithms determine which mathematical operations to apply to the data to characterize behaviors of interest. There is a wide spectrum of AI/ML model algorithms, such as computer vision, clustering, neural network/deep learning, and natural language processing, just to name a few. Building a model that performs well depends on the type of data at hand, selected algorithm, and the desired behavior to predict. For example, the second Industry Example below applies a neural network algorithm in its model, while the third Industry Example uses hyperspectral imagery for its anomaly detection model. The fourth Industry Example creates an automated capability with custom imagery classifiers to build a computer vision model for humanitarian assistance/disaster response to save time when reviewing post-event imagery.

5.1 Industry Example #1: Synthetic AI/ML Training Datasets Using GPU Acceleration

One of the continued challenges associated with democratizing AI for national security is the availability and reliability of machine learning training data. Significant time and research are still required to improve efficiency of creating training datasets. Developing algorithms for use with few training data examples also presents greater challenges in accuracy and function. These challenges are true of computer vision applications applied to satellite imagery. AI practitioners often find it difficult to find a geographically diverse set of training examples of certain object types such as aircraft, or finding examples of certain objects at all. Further, the performance of neural network models is often limited by the availability of large data sets, accelerated compute power to handle the training, and necessary the tools to derive the desired insights.

To address these challenges, Maxar researchers leveraged NVIDIA hardware and software to develop novel synthetic data generation and augmentation techniques to enhance low/zero-sample learning in satellite imagery. The Maxar team also proposed a hierarchical detection approach to improve the utility of synthetic training samples. NVIDIA GPUs allowed this process to run 40 times faster compared to the use of traditional central processing units (CPUs). As AI/ML tools proliferate, the ability to leverage synthetic training data to enhance algorithm performance will be an important capability for practitioners that will enable AI even when real training data samples are limited.

5.2 Industry Example #2: Generating Synthetic Data for Neural Network Training

For many use cases, the specific type of data to be detected simply does not exist in large enough quantities to enable machine learning techniques to work. In one recent project, Clarifai worked to determine the feasibility of using synthetic data to train models to detect objects for which very limited images exist. In this use case, Clarifai generated CAD models of objects which are known to exist, but of which limited imagery is available and used automated scene generation techniques to create scenes containing these objects. A combination of these auto-generated scenes and the limited available data allowed for the creation of a robust ML detection model.

5.3 Industry Example #3: Anomaly Detection In Hyperspectral Imagery

The Space Dynamics Laboratory (SDL) and Naval Research Laboratory (NRL) often collaborate to understand patterns and behavior through sensors. Sensor and satellite imagery have been an important source of information for supporting these efforts. Hyperspectral images provide deep, rich information for every pixel within an image. An ongoing SDL/NRL effort in pixel-based anomaly detection has been performing unsupervised training of neural networks to identify the anomalous pixels within a hyperspectral image. SDL researchers have modified the training process with autoencoders to achieve compelling results in detection with a baseline image (Forest Radiance I) as well as other hyperspectral sensors.

5.4 Industry Example #4: AI/ML for CV for HADR Missions

Humanitarian Assistance / Disaster Response (HADR) missions are unpredictable in time and place. Whether the example is a regional fire, or a battle damage assessment, or flood damage, there is a crucial need for immediate and automated imagery support. AI/ML can scale where manual assessments cannot. Google has created a workflow to ingest imagery into Google Cloud, label damage assessment classifiers, train models, test the models, and publish these models for all users to see. This applies to disasters such as fires, earthquakes, armed conflict, and more.

Acknowledgments

Todd M. Bacastow, Senior Director, Maxar
Mark Knapp, VP, Defense & Intelligence, Preligens
Patrick Neary, Ph.D., Research Scientist, Space Dynamics Laboratory
Suzy Park, Data Scientist, Guidehouse
Don Polaski, Chief Scientist, Booz Allen Hamilton
Mark Ronlov, Senior Account Manager, NVIDIA
Jeff Spugnardi, CTO, Spugnardi Services

USGIF Staff
Ronda Schrenk, Chief Executive Officer
Christy Monaco, Vice President of Programs
Brad Causey, Managing Editor
USGIF Interns Molly Brady, Jessica Dorsch, Simon Nguyen, Sean Rodgers, Matt Sapsara, Christine Yoo

About USGIF

The United States Geospatial Intelligence Foundation (USGIF) is a 501(c)(3) nonprofit educational foundation dedicated to promoting the geospatial intelligence tradecraft and developing a stronger GEOINT community with government, industry, academia, professional organizations, and individuals who develop and apply geospatial intelligence to address national security challenges. USGIF achieves its mission through various programs and events and by building the community, advancing the tradecraft, and accelerating innovation.

Sponsors

MAXAR ORACLE Space Dynamics Laboratory, Utah State University Research Foundation

Warning
This document is a USGIF White Paper and is therefore not an official position of the USGIF membership. It is distributed for review and comment. It is subject to change without notice. Further, this White Paper should not be referenced as required or mandatory technology in procurements.