8/27/2018

Machine Learning and Artificial Intelligence

Advancements for Electrical Inspection

Bob Williams, PSM, CP, GISP
SURVEYING AND MAPPING, LLC
Introduction

Imagine if utilities had the ability to receive advice from the most knowledgeable expert in the profession, at a moment’s notice, with unlimited capacity, across the entire organization simultaneously. Artificial Intelligence (AI) consist of software and hardware devices that offer the grand possibility that these expectations can be achieved. The software and hardware associated with AI and Machine Learning (ML) are capable of processing 500 gigabytes per second, or the equivalent of a million books per second for very small transactional costs. AI and ML engines can be trained to consistently repeat uniform answers to complex questions quickly.

One of the most recognized events that made the general public aware of the power of AI occurred in January 2011. IBM’s Watson, a very large computer beat long running Jeopardy champion Ken Jennings, who jokingly writes on his final entry “I for one welcome our new computer overlords.” Similar exciting advancements can be witnessed all around us, every day.

Jeff Bezos, Amazon’s Founder, Chairman, and Chief Executive Officer mentioned AI and ML in his letter to annual stockholders referring to Amazon Web Services. Bezo’s said, “Big trends are not that hard to spot. We are in the middle of one right now. Machine Learning and Artificial Intelligence.”

Artificial Intelligence & Machine Learning

AI is the broadest of term, applying to any technique that enables computers to mimic human intelligence, using logic, if-then rules, decision trees, Neural Networks, and Machine Learning. ML is a subset of AI that includes statistical techniques that enable machines to improve a task with experience. Big data is large volumes of data used for computational analysis, to reveal patterns or trends. Within the field of data analytics, ML is a method used to devise complex models and algorithms that lend to prediction and is also referred to as predictive analytics. Analytical models allow researchers, data scientists, engineers, and analysts to produce reliable, repeatable decisions and results to uncover hidden insights through learning from historical relationships and trends in the data.

Within ML, Neural Networks have been an important development to teach computers to think and understand the world similar to how humans process information, while retaining the advantages of a computers speed, accuracy and lack of bias. A Neural Network is a computer system designed to work by classifying information similar to the same way a human brain functions. The system can be taught to recognize images, and classify the images, including the components or sub-elements that are contained within the images. Essentially, Neural Networks function on a system of probability based on input data to make statements, decisions or predictions with a degree of certainty or statistical probability. With the addition of a feedback or training sequences of right or wrong answers, the software improves the approach and answers on future tasks.
Several commercial AI and ML super computer engines exist that can be utilized. The transactional “pay as you use” business model provides a flexible purchasing threshold, in a cloud processing scenario. Today, no single AI engine can accomplish all the tasks that are required for electric infrastructure inspection. Multiple commercially available and open source engines can be utilized, with each one having distinct advantages. A few commercially available engines and companies leading the AI advancements include:

- IBM
- Microsoft
- Amazon
- Intel
- Google

- Apple
- Facebook
- Spotify
- Uber
- Salesforce

Project SiMON

Project SiMON is an undertaking initially focused on electric transmission and distribution inspection, but will eventually be leveraged across all engineering and survey disciplines. SiMON consists of a set of processes, procedures and software to organize, filter, and analyze large volumes of remotely sensed datasets. Anomaly reports are generated, including predictive analytics for establishing operations and maintenance priorities. The methods utilize Big Data, AI and ML as a decision support tool to improve business operations to aid in the development of strategic maintenance plans to improve reliability.

The origin of the clever project name is derived from a centuries old child’s game called Simon Says or Simple Simon. The game involves 3 or more players, where 1 player takes the role of “Simon” and issues instructions for the others to follow, but only if prefaced with the phrase "Simon Says". If a player doesn’t follow the rules or instructions, they are eliminated from the game. Similarly, an electronic memory game invented by Ralph H. Baer and Howard J. Morrison, with software programming by Lenny Cope was introduced in 1978 called Simon. The device creates a series of tones and lights and requires a user with strong memory skills to repeat the sequence. If the player succeeds, the series becomes progressively longer and more complex. The original version was manufactured and distributed by Milton Bradley and later by Hasbro. Simon was an immediate success, becoming a pop culture symbol of the 1970s and 1980s, with versions of the game still sold today.
**Process and Procedures**

The inspection service is a set of processes, procedures, software and instruments to organize, filter, and analyze large, remotely sensed datasets. The datasets are collected through a variety of methods, including boots-on-the-ground, aerial and mobile mapping inspection techniques. The initial development will focus on structures and individual component anomalies to support operation, maintenance and integrity of an electric network. The techniques will change the way inspection and engineering datasets are gathered and analyzed across multiple engineering disciplines.

The inspection techniques utilize manned, unmanned aircraft, and mobile mapping platforms to gather large volumes of remotely sensed data sets for analysis. The datasets consist of close range oblique photos, Infrared (IR) and Ultraviolet (UV) imagery, coupled with high-density LiDAR gathered in a single aerial or mobile mapping mission. The composite view or virtual side-by-side analysis technique, both automated and supervised, create a baseline temporal analysis of electric infrastructure year-over-year.

*Component analysis from multiple datasets and spectrums*
The utilization of 3D scanning instruments and imaging sensors that span a large swath of the electromagnetic spectrum for both the visible and invisible range, provide data for a sophisticated analysis approach. The current Unmanned Aerial Systems (UAS) are equipped with a 4 sensor payload configuration that are within the 55 pound UAS gross weight allowance for the current FAA Part 107 regulations. The UAS acquires 50 points per square meter, high density LiDAR with a vertical accuracy consistently better than a .10 foot RMSE on hard surfaces relative to the accuracy of the ground control surveys. These UAS are not the typical drones found under the tree on Christmas morning. With platform and payload, the each UAS cost in excess of $300,000 with the performance to match the investment.

The end-to-end process utilizes a Collect, Analyze, Predict and Prioritize (CAPP) process. The software developed to query the AI engines consist of a library of Application Programming Interface (API) models. The content library and knowledge base for the API development is being built with every aerial mission undertaken. Example concepts include: What is it? Where is it? What is wrong? When will it fail? Why is it failing? What is the priority? What is the cost to repair?

Based upon the content library, AI and ML engines analyze the datasets and the structures and individual components. Supported by Subject Matter Experts (SMEs), the process recognizes the obvious maintenance issues and will eventually mature to predict when the component may fail. The software generates a report based upon a utilities risk, urgency or priorities.

The first processing iteration is performed on a Windows desktop application that will allow for data management, processing, inventory and indexing of the aerial imagery locally. All images are georeferenced and associated with a structure identification number. Initially the images, are processed on local servers to ensure the metadata is populated and associated with the client database successfully. The images are then uploaded to the cloud for analysis where additional processing is performed.
Some of the processing tasks include cropping the individual image anomalies and compressing the files for rapid display. The cloud processing permits unlimited scaling on demand to increase the processing power under a large volume of image datasets and an ever increasing library of AI training sources. Reduced thumbnail images and basemap image viewers are synched together so that a selection on any image will be reflected in all other views. Some of the metadata associated with the datasets include project, circuit name, image type, acquisition date and inspector. Some of the initial functions include:

- Identify Structure Location & ID
- Identify Component
- Locate Anomaly and Nearest Structure
- Draw Anomaly Box
- Delete Anomaly Box
- Add Note – Popup box to allow the SME to comment
- Clip and Ship to Client
- Generate Anomaly Report
- Locate Encroachment from LiDAR
- Calculate Encroachment Distance
- Show vertical aerial photo toggle
- Show oblique aerial photo toggle
- Highlight unviewed images toggle

**Electric Transmission Project Example**

Coat-tailing the UAS crews with the ground inspection crews enable the aerial datasets to be acquired along with GPS ground control and meteorological data during the same mobilization and level of crew effort. One flight profile, with many sensors increases benefit and overall efficiency of the ground-aerial inspection.

Currently, 4 datasets are being collected with the ground and aerial inspection covering 1,150 electric transmission miles and over 7,000 structures. At the project’s completion, it is estimated that crews will have gathered approximately ¾ million images that can be processed into the AI and ML software engines. The project objectives, scope of work and delivery items include:

- 2 Inspections – Ground & Air, single mobilization
- Duplicate the exact sensor location year-over-year
- Precision Measurements from LiDAR
- Aerial Targeting (Survey Ground Control)
- Meteorological Observations during the flights
- HD Handheld Digital Cameras ground perspective
- Populated Attributes in ArcGIS Database
- Anomaly and defect inspection report (patrol log), .pdf format
- Flight plan and executed GPS trajectories, ArcGIS or .kmz format
- Daily flight logs, crew and equipment reporting, .pdf format
- Survey control report .xlsx and .pdf format
- LiDAR Calibration and map accuracy report, .xlsx and .pdf format
- Auto-Classified, LiDAR point cloud in .las format (for vegetation encroachments)
- Geo-tagged, Thermal imagery of anomalies in .jpeg format,
- Geo-tagged, RGB imagery of ground and aerial obliques in .jpeg format
**Project Statistics**

**Oblique Color Imagery**
254,000+ photos  
3.8 TB

**Oblique Thermal Imagery**
254,000+ images  
.40 TB

**Vertical Nadir Imagery**
169,000+ photos  
2.5 TB

**LiDAR**
50 ppsm  
11.5 TB
Summary

AI and ML software engines are being utilized to enhance traditional electric infrastructure inspection. The ML training experience is gained from acquiring and processing hundreds of thousands of images from both the visible and invisible electromagnetic spectrum, coupled with HD LiDAR. At his point in the evolution of the science, SMEs still validate the automated results. Current automation is estimated at 10% to 15% of the entire process, supplemented by SME performing 85% to 90% of the inspection analysis. Through time, and analyzing millions of image and LiDAR data sets, the AI and ML results will mature to be consistent, uniform and accurate. It is expected that future results will be inverted so that automation will be achieved between the 85% to 95% level, with SME validating the computer analysis. The planned development timeline to achieve an 85% or greater automation is stated below.

- **Supervised Phase** – Current and ongoing expected to last 2.5 to 3 years.

- **Transition Phase** – Incremental reliance on Artificial Intelligence and Machine Learning for assessment and reporting, with Subject Matter Expert verification. Current and ongoing with a 10% to 15% automated analysis.

- **Unsupervised Phase** – 3 to 5 years to achieve an 85% to 95% automation with Subject Matter Expert providing Quality Assurance.

Utilities can rapidly leverage and exploit a mature cognitive search and content analytic engines. AI and ML will allow developers to quickly ingest data to find hidden patterns and answers, enabling better decisions across functions, which will be used to generate hypotheses, predictive analytics, gather massive evidence to make better business decisions. The technology will decrease operating costs, focus maintenance priorities and improve reliability. The early adoptive stage utilizing unsettled technology can be challenging. However, an early adaptation with a sustained commitment to change traditional inspection methods will yield a great return for utilities.
Glossary of Terms

**Artificial Intelligence (AI)** – A.I. is the broadest of term, applying to any technique that enables computers to mimic human intelligence, using logic, if-then rules, decision trees and machine learning.

**Machine Learning (ML)** – The subset of A.I. that includes statistical techniques that enable machines to improve at task with experience.

**Big Data** – Large volumes of data sets that are used for computational analysis, to reveal patterns or trends.

**Deep Learning** – The subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like speech and image recognition, by exposing multilayered neural networks to vast amounts of data.

**Neural Networks** – Software constructions modeled after the way adaptable networks of neurons in the brain are understood to work, rather than through rigid instructions predetermined by humans.

**Bayesian Networks** – A probabilistic graphical model or type of statistical model that represents a set of variables and their conditional dependencies. For example, a Bayesian network could represent the probabilistic relationships between electric outages and a individual electric grid component anomaly. Given the component anomaly type, the Bayesian Network can be used to compute the probabilities of an outage.

**Clustering** – During the supervised learning phase of inputting data for training, a subject matter expert selects or targets input features to be utilized in the learning models. In clustering or unsupervised learning, the target features are not given in the training examples. The goal is to construct a natural classification that can be used to cluster the data. The general idea behind clustering is to partition the examples into clusters or classes. Each class predicts feature values for the examples in the class. Each clustering has a prediction error on the predictions. The best clustering is the one that minimizes the error.

**Application Programming Interface** - API is a software intermediary that allows two applications to talk to each other. Each time you use an app like Facebook, send an instant message, or check the weather on your phone, you’re using an API.

**UAV** - An unmanned aerial vehicle (UAV), commonly known as a drone, is an aircraft without a human pilot aboard. UAVs are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers.

**UAS** – An unmanned aircraft system (UAS), sometimes called a drone encompasses the aerial platform, communacions and navigation systems, IMU, GPS and various sensor payloads all tightly coupled to function together.

**GPS** - The GPS (Global Positioning System) is a "constellation" of satellites that orbit the Earth and make it possible for people with ground receivers to pinpoint their geographic location.
**IMU** - An inertial measurement unit (IMU) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometers and gyroscopes, sometimes also magnetometers. IMUs are typically used to maneuver aircraft, including unmanned aerial vehicles (UAVs), among many others, and spacecraft, including satellites and landers. Recent developments allow for the production of IMU-enabled GPS devices. An IMU allows a GPS receiver to work when GPS-signals are unavailable, such as in tunnels, inside buildings, or when electronic interference is present.