GSAW 2019 Tutorial I:

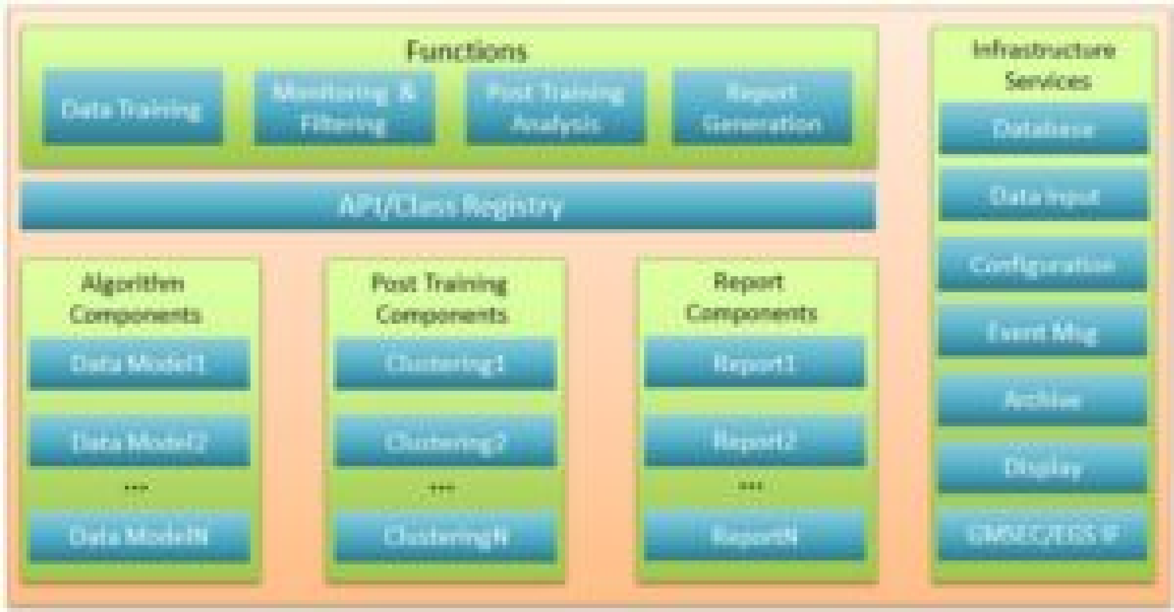
Build a Machine Learning Infrastructure in the Ground Enterprise for Space Missions

Length: Half day

Overview:
A space mission with both space and ground assets can be regarded as a dynamic system that is time dependent and nondeterministic. Situational awareness of a dynamic system is defined as the ability to perceive, analyze, and predict its own behaviors, which is crucial to enable data monitoring for anomaly detection, dynamic data filtering, and sensor data quality assessments. The dynamic model of situational awareness provides important insights into the interactions between a machine learning system and its managed elements such as the space and ground assets of a space mission. The architectural model for machine learning (ML) involves four key data processing blocks: data training to create system situational awareness, dynamic monitoring and filtering to determine true system states, post training analysis with unsupervised ML approach to assess the data quality and system operational status, and a decision-making process to generate appropriate actions for system self-healing or self-optimizing. The ML in the context of situation awareness trains data models with the normal behavior or patterns of a dynamical system, detects the deviations from its normal patterns and characterizes the deviations with quantitative data quality metrics. An anomaly in this approach is defined as the unexpected and persistent pattern changes from its normal behaviors.

The application of a ML framework in an operational environment brings considerable challenges, which include the large numbers of datasets, very large data volumes, diverse data types, and defective datasets with outliers that affect data training outcomes. Data training algorithms in operational environments must be robust, efficient, and accurate. Thus, a ML system for space missions from a single spacecraft to multi-satellite constellation requires flexibility in selecting different data models for datasets with different data patterns and scalability in managing large number of datasets and large data volumes. Furthermore, ML solutions consists a large number of application portfolio for missions with different orbit characteristics, such as LEO, MEO, or GEO missions, which require different ML algorithm setup and representations. The enterprise approach for ML systems in operational environments provides common functions, software services and an Application Programming infrastructure for all missions, while allowing engineers to develop mission specific algorithms that can be deployed as the plug-and-play components. The component approach for ML algorithms enables engineers to focus on the ML algorithm specific to the domain datasets without expending resources on the logistics and infrastructure required for setting up complex ML applications. The enterprise approach provides scalability, extensibility, and flexibility, and reduces the cost and development cycles for ML solutions in space missions.

The ML enterprise architecture provides well-defined functions, operational concepts, and standard interfaces. The common functions are data training, data monitoring and filtering, post training analysis, and report generations. The components in the ML enterprise include the algorithm component for data training, the post training analysis components and report generation components. Post-training analysis evaluates system operational status and sensor data quality, and implements clustering techniques with quantitative data quality metrics derived from data training outcomes. Report generation components provide the flexibility needed to meet specific requirements in content and format for different missions in presenting the data training and post training analysis results. Common infrastructure and services include data input, data archive, global configuration, database, system messaging, data display and the GMSEC/EGS interfaces.



This enterprise architecture provides interfaces allow integration of the ML system into a mission ground system enterprise for space missions, using such standard messaging formats and capabilities available in the GMSEC architecture and the future Enterprise Ground Services implementation. The interface between ML systems and the ground enterprise includes publishing event and heart-beat messages across the Enterprise Bus, and providing ML services for predicting the behavior of telemetry datasets that can be used by other components in the ground system enterprise for further analysis and display.

This tutorial consists of the following two parts;

The ML framework and formulism for dynamical systems, which include the following topics

1. The ML architecture model based on situation awareness theory.
2. The data representation and data training approach for spacecraft datasets.
3. The data monitoring in ML, and how an anomaly is defined in ML framework
4. The post-training analysis to obtain actionable information from the training outcomes of large sensor datasets

The enterprise architecture for ML systems in operational environments with the following topics

1. The challenges for deploying the ML solutions in operational environments, and why the enterprise approach is needed.
2. The enterprise approach for ML solutions leads a scalable and extensible enterprise architecture that treats the domain specific algorithms as the plug and playing components.
3. The infrastructure and services needed for ML algorithm components.
4. The APIs and deployment procedures for ML algorithm components.
5. ML services and interface to the enterprise ground architecture, such as GMSEC/EGS reference architecture

Reference:

[1] Mica R. Endsley, “Toward a Theory of Situation Awareness in Dynamic Systems”, Human Factors, 1995 The Journal of the Human Factors and Ergonomics Society 37(1):32-64.

[2] Zhenping Li, J.P. Douglas, and Ken Mitchell, “Creating Situational Awareness in Satellite Data Trending and Monitoring”, 32nd Space Symposium, April 11-12, 2016, Colorado Springs, Colorado. http://www.spacesymposium.org/tracks/technical-track/papers

[3] Zhenping Li, "Creating Situational Awareness in Spacecraft Operations with the Machine Learning Approach", 2016 AMOS Conference, September, 20-23, Maui, Hawaii. http://www.amostech.com/TechnicalPapers/2016/Poster/Li.pdf.

[4] Zhenping Li, David Pogorzala, Ken Mitchell, J.P. Douglas, "Adaptive trending and limit monitoring algorithm for GOES-R ABI radiometric parameters" GSICS Quarterly Newsletter, Summer 2015 Issue, http://dx.doi.org/10.7289/V5XK8CHN#page9.

[5] Zhenping Li, "Machine Learning in Spacecraft Ground Systems", Proceedings of 6th IEEE International Conference on Space Mission Challenges for Information Technology, 2017, to be published.

[6] Zhenping Li, Ken Mitchell, Biruh Tesfaye, and Data Pogorzala, "Monitoring GOES-R Advance Baseline Imager(ABI) Radiometric Performances with a Machine Learning System", CALCON 2018 Conference Proceedings, June, 2018. Logan Utah. To be published in July 2018.

Instructor: Zhenping Li, Arctic Slope Technical Services (ASTS)

Biography:
Zhenping Li: Received Ph.D in Physics from The University of Tennessee in 1992, a Master's degree in computer science from Johns Hopkins University in 2003, he joined ASTS in 2013. His main focus areas are algorithm development for satellite instrument data processing and the application of machine learning algorithms in support of satellite operations.

Description of Intended Students and Prerequisites:
The target audience includes systems engineers and software developers who are interested in machine learning, the telemetry data modeling and analysis. Satellite engineers and mission operators who manage and monitor satellites and its instrument health and safety. Knowledge of satellite operations is very helpful, and basic knowledge of the machine learning is needed.

What can Attendees Expect to Learn:
The attendees will learn about machine learning, an enterprise approach to develop machine learning solutions, and how to provide ML services to enterprise ground systems, such as GMSEC or enterprise ground services (EGS).