JPL Activities in AI and Data Science

Dr. Richard Doyle
Program Manager, Information and Data Science
Jet Propulsion Laboratory
California Institute of Technology

2nd Workshop on Artificial Intelligence and Data Science for Space and Earth Science
February 9, 2021
AI for Data Science

with contributions from

Dan Crichton
JPL Leader
Center for Data Science and Technology
Tackling Data Science Challenges at JPL

• JPL is engaging Data Science and AI / ML technologies and methodologies across science, engineering, and mission operations

• JPL has a Data Science Working Group focused on building and implementing an institution-wide strategy for Data Science and AI / ML

• Over 50 pilot projects, larger projectized efforts, plus partnerships and events.
Data Lifecycle Model for NASA Missions
From Onboard Computing to Scalable Data Analytics

Emerging Solutions
• Next-Generation Flight Computing
• Onboard Data Analytics

Observational Platforms and Flight Computing

Emerging Solutions
• Intelligent Ground Stations
• Agile Mission Operations

Emerging Solutions
• Data-Driven Discovery from Archives
• Scalable Computation and Storage

Interactive Analytics and Visualization and Decision Support

SMAP (Today): 485 GB/day
NISAR (2021): 86 TB/day

Scaling Pressures Expose the Need for an Integrated End-to-End Data and Computational Architecture
First time machine learning has been used to find previously unknown craters on the Red Planet

- COSMIC is a capability to monitor the entire Martian surface for transient science events, targeted to future onboard use

- Tested on a 112,000 image database to search for fresh impacts

- Machine learning can help accelerate scientific discoveries

- NASA/JPL Press release picked up by Universe Today, Analytics Insight, Vice, NPR, and Google Space News

COSMIC (PI Lukas Mandrake, Kiri Wagstaff, Gary Doran, Steven Lu, Umaa Rebbapragada)  
COSMIC = Capturing Onboard Summarization to Monitor Image Change
AI and ML Applied to Earth Science

Deep Learning for Methane Point Source Detection

Reduced latency from 3 months to 48 hours

Machine Learning Assist to Predicting Hurricane Intensity

Improved forecasting in the Atlantic basin to >70%


AI for Autonomy

with contributions from

John Day
JPL Leader
Center for Autonomy
Vision for the Future of Autonomy at JPL

• Space exploration involves spacecraft operating in harsh and unforgiving environments

• JPL is pioneering resilient, self-aware, and autonomous systems able to weigh risk and make decisions locally to ensure that tomorrow’s missions are a success

• Key characteristics of future missions:
  • Goal-directed operations, allowing operators to focus on objectives and oversight
  • Self-sufficient planning, scheduling, and control, including management of resources and redundancy, and recovery from anomalies
  • Real-time assessment of situations given set of objectives and utilizing models of system and environment
  • Capabilities for learning and model adaptation based on observations of system and environment
Key Capabilities for Autonomous Systems

- Feature Detection, Data Interpretation
- Real-time Adaptation, Coordinated Operations, Risk and Resource-aware Planning
- High-performance, Fault-tolerant, Multi-processor Computing
- Dexterous Manipulation and Mobility on any Surface

NASA Jet Propulsion Laboratory
California Institute of Technology
Autonomy Focus Areas

- **Architecture**
  - Mission-wide evolvable architecture that enables the integration and deployment of state-of-the-art control and reasoning technologies

- **Methodology**
  - Processes and tools for assembly, coordination, and analysis of information in a systematic fashion that ensures completeness and accuracy, resulting in a reliable, affordable, operable system

- **Computing**
  - High-performance, fault-tolerant, multi-processor computing platforms

- **Assessments and guarantees of system behavior**
  - Enabled by principled design techniques and advancements in simulation and formal methods

- **Iterative development**
  - Iterative development of operational capabilities via rapid prototyping, progressively increasing the scope of the deployed autonomy capability

- **Partnerships and collaborations**
  - Leverage external capabilities in autonomy, AI and related technologies

![Resilient Spacecraft Executive Architecture](image)

![Model-based Probabilistic Risk Assessment](image)
Staged Evolution of Capability

• Stage 1: “Resilient System”
  • System performs resource management and health management functions. Executes “tactical” activity plans provided by operations team. Uses and adapts models of internal state. Control via closed-loop commanding. Adapts detailed plan to address minor anomalies.

• Stage 2: “Independent System”
  • System generates tactical activity plan based on science directives (“strategic plan”) provided by science team. Uses and adapts models of internal state and environment. Reduced mission operations team.

• Stage 3: “Self-Directed System”
  • System develops science strategic plan and tactical plans based on high-level objectives. Responds to novelty by adjusting plans within context of objectives. Reduced science operations team.
The Importance of Partnering
Partnering Strategy

• NASA
  • Working with HQ – SMD and DTX, and Centers – GSFC, ARC, LaRC… on Strategy for AI / ML activities for science and enterprise
  • GSFC – Center for Helioanalytics, HPC benchmarking, climate simulation…

• Academia
  • Caltech Joint Center in Data Science
  • Training of student interns using JPL use cases
  • Collaborations with UC, CMU, MIT

• Government
  • Interoperability of archives
  • Engagement of technologies and data scientists across agencies
  • Collaboration with MIT Lincoln Lab

• Industry / Open Source
  • Leverage and collaboration on big data technologies and cloud services
  • Form public-private research partnerships
  • Collaborations with Amazon Web Services and the Apache Foundation

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.