Levels of On-board Autonomy

Application of ML to Mission Architecture

Machine Learning & Instrument Autonomy Group
398j

Jet Propulsion Laboratory
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Data Science in Different Mission Contexts

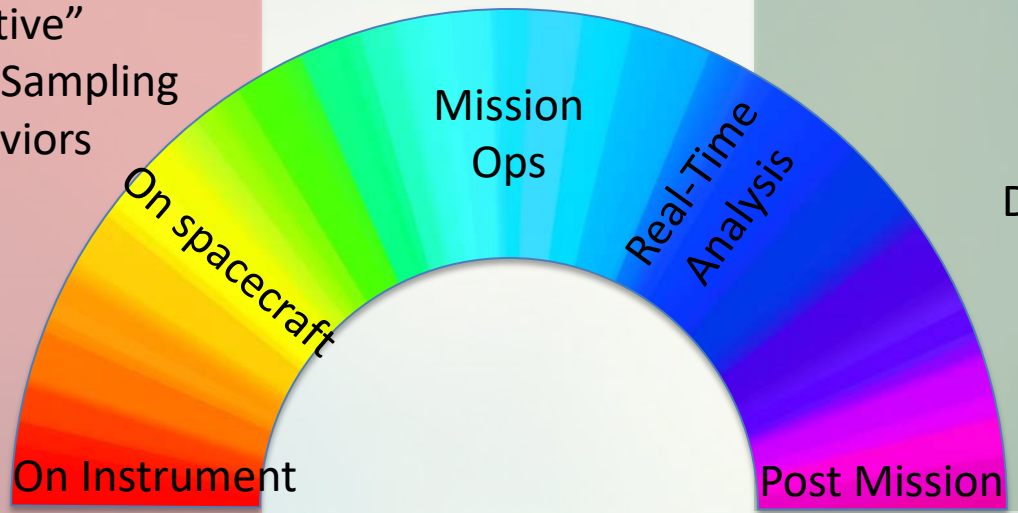
(often similar algorithms behind the scenes)

Commonly called "Autonomy"

Health Monitoring
Navigation / Optimization
Uplink Prioritization
"Reactive / Adaptive"
Intelligent Targeting / Sampling
Closed-loop Behaviors

On-board science
Intelligent filtering
Data Prioritization
Anomaly detection

Decision Support
Anomaly Detection
Health Monitoring
Planning



Commonly called "Data Mining"

Discovery Support
Advisory Systems
Data Characterization
Model Generation

Analogy (for next slide)

Autonomy solutions descend from mere ideas to become incorporated into the solid bedrock of trusted technology

Often disruptive to heritage surface, but so was every other technology we use…

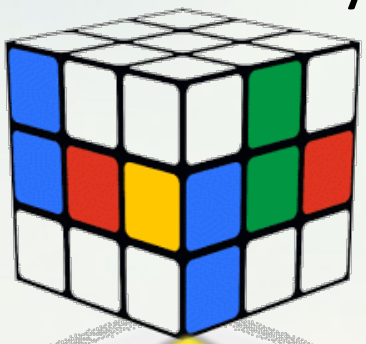
Analogy	Heritage	Auto-nomy	Technology	Representative Use Case
Exo	No complete systems to test, partial solutions exist	6	Self-learning, close-looped explorer that operates independently in novel environment	Robot soldier / fire-n-forget probes more aligned with robotics-type group
			Building intuition about environment "Formulate relation between observations and make obs to verify hypothesis."	Very complex / alien / unknown environment and extreme durations between communication chances
Strato	Solutions exist in research but need validation in applied setting	5	Autonomous system mostly trained in lab but "updates/adapts" its systems in the field	Fully autonomous cars, damage-tolerant explorer, unpredictable & unstable environment
			Observation reasoning ”Getting meaningful results by doing this kind of observations, explore similar options."	Poorly defined or unknown science goals, virtually zero ground comm
			Decision explanation "This is why I think this observation is important"	Regular (but infrequent) ground communication to help refine explorer behavior
Tropo	General solutions ready but not yet on mission	4	Anomaly Detection ”find things that are new/stand-out”	Novel environment, opportunistic science during traversal
			RadHard algorithms “Trade-off radiation shielding for error-tolerant algorithms”	High radiation environments
Surface	Revolutionary heritage in the making now	3	Reactive Targeting "That's interesting. Measure again or with other sensors"	Transient events, very high bandwidth instruments, opportunistic science
			Predictive Sampling ”Lots of interest here, but still have a long way to go, so sample carefully."	Long periods between communication opportunities
			Safe Path Finding / Navigation solutions	Changing environment, exploring beyond oversight
			Goal-seeking "Obtain stationary position X meters above surface"	MSL EDL, health monitoring, autonav
Crust	Space heritage	2	Science processing to summarize observations "Return knowledge not data"	Bandwidth conservation
			Bandwidth, power, schedule, memory optimization "intelligent self-planning"	Agile exploration
			Template Matching “Interesting things like this”	Auto-targeting, opportunistic science, agile exploration
Mantle	Well Trusted	1	Thresholds, alarms, triggers. Highly complex programs. “If this then that."	MER EDL, well understood environments, poor communication
Core	Human-centric	0	Ground-loop systems, Safe Mode concept "Radio back data, receive instructions"	Short comm round trip, plentiful bandwidth

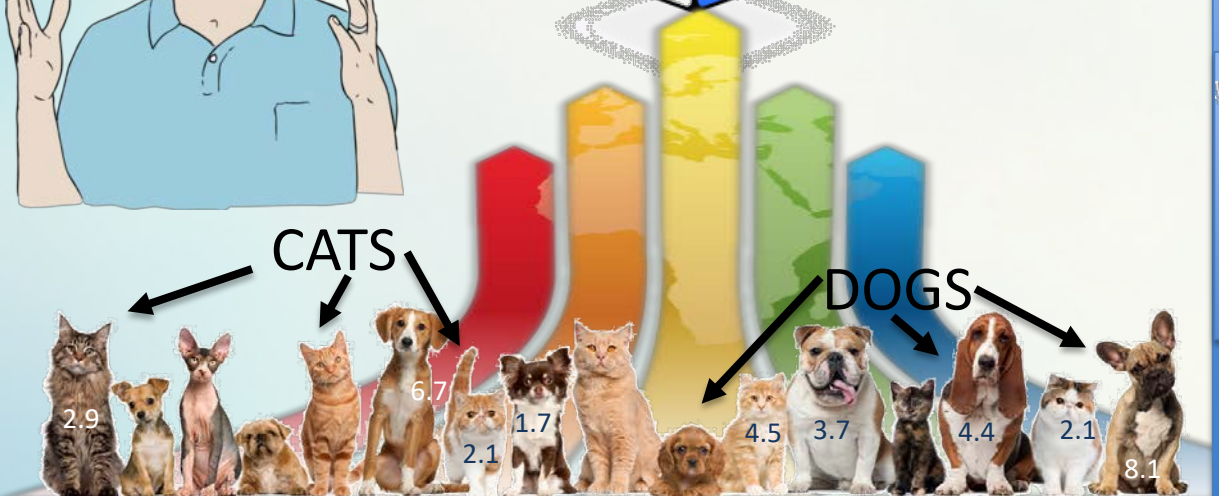
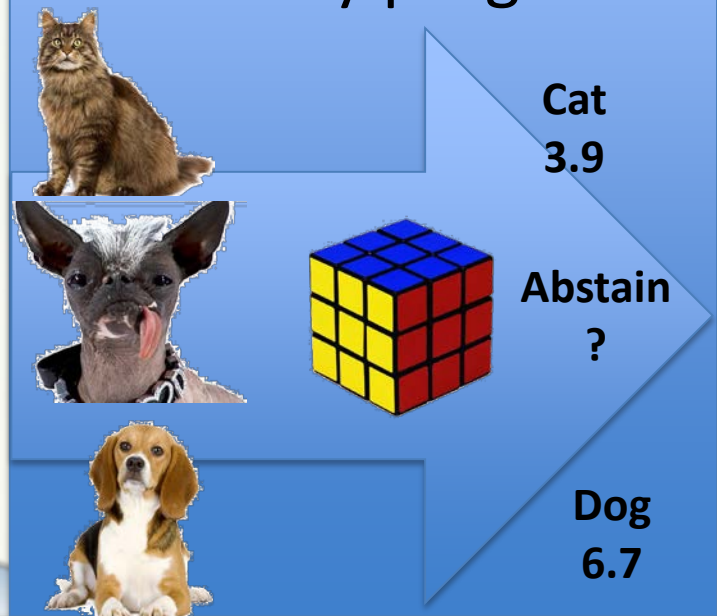
Where's the Learning?

Most Machine Learning systems "Learn" during self-construction based on statistics and large datasets.

"Distinguish cats from dogs and their age. Here are examples for training."

Self-assembly





Finished product no longer learns, but can do things humans can't easily program: