Autonomously Learning Mobility Limits

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Problem
Maximize performance and mobility under safety constraints for military ground vehicles and powertrain systems operating in uncertain environments with varying loading and in-field modifications.

Solution: Learning Reference Governor (LRG)
LRG is an add-on unit that acts as a safety supervisor for the commands passed to the existing/legacy systems. LRG learns to operate the system to achieve high performance while satisfying safety constraints through in-field experiments or simulations on high-fidelity models.

Safety-Enforced Learning [1]:
- Ensuring safety for all time (both during and after learning).
- Estimating the response bounds of constrained variables, starting with conservative design and reducing conservativeness as gaining knowledge about system response while ensuring safety.
- Guaranteeing monotonic performance improvement, response bound estimate convergence, and finite-time convergence of modified reference to command (see [1] for more details).

Learning from Constraint-Violation Occurrence [2]:
- Allowing occasional constraint violation during learning and guaranteeing constraint enforcement after learning.
- Starting with aggressive design and tightening a safety margin function \( \Gamma(v) \) in response to constraint violations during learning.
- Guaranteeing \( \Gamma(v) \) function convergence, and asymptotic convergence of modified reference to command (see [2] for more details).

Safety-Enforced Learning Applied to Rollover Protection for Tank Truck with Fuel Sloshing [3]:
Learning at/near the military base before mission Executing mission after learning

Experimental Validation for Misfire Avoidance in SI Engine [5]:
- Command - Experiment - Adaptive EKF
- Before Learning - After Learning - (before change)