NRI: FND: COLLAB: Design of Dynamic Multibehavioral Robots

New tools to consider design tradeoff and enable more capable robotic systems

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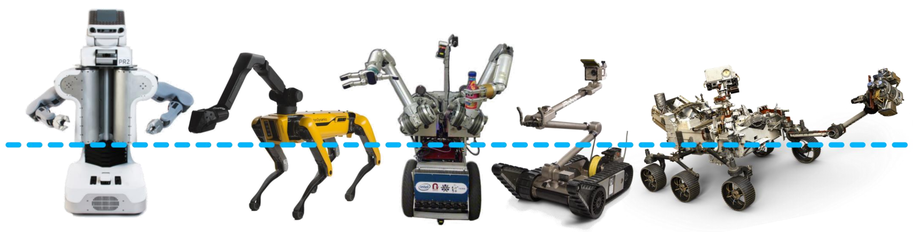
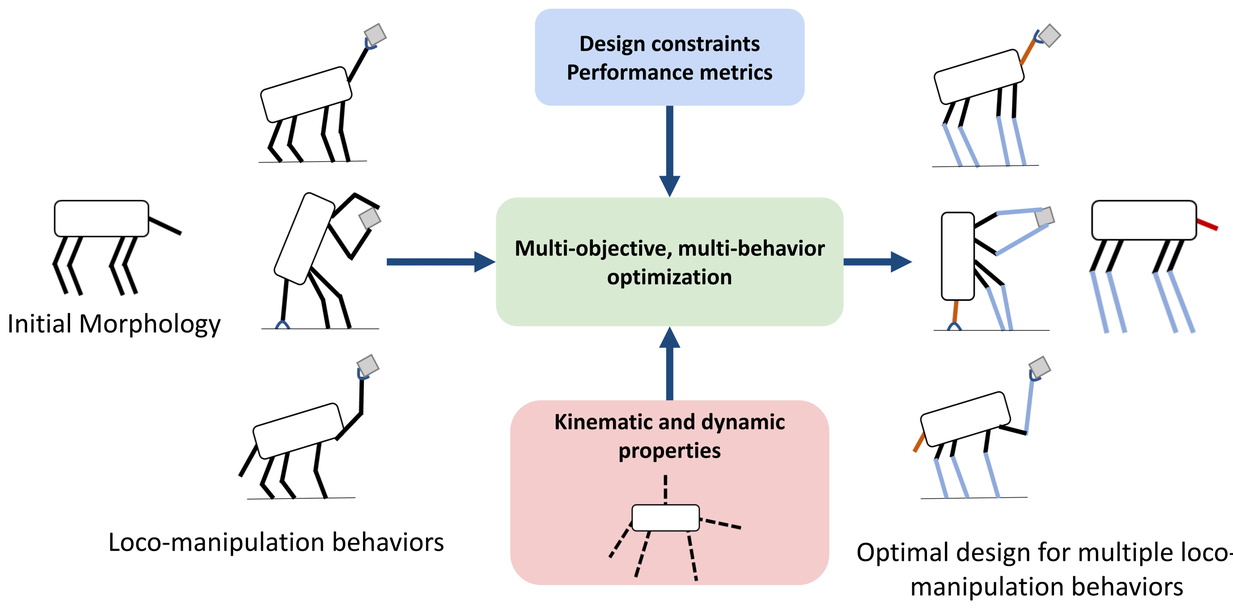
Challenge: How do we design a robot that is good at multiple behaviors? For example, how do we design one robot for both locomotion and manipulation?

Scientific Impact: The analytical and computational techniques we create will contribute toward establishing a systematic paradigm for robot design.



Most mobile manipulation systems are built by combining independent manipulation and locomotion system.



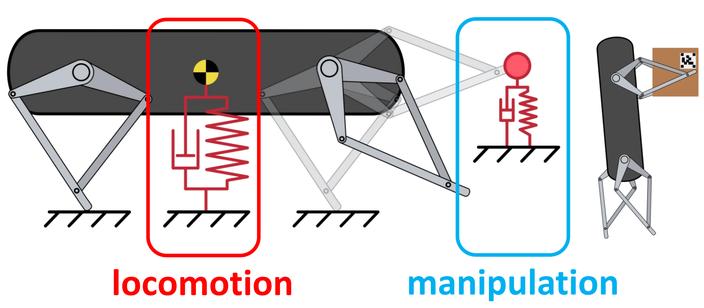
Overall Solution: Formulate dynamic behaviors as objective functions, solve multi-objective optimization problem involving design parameters, e.g. spring stiffness and geometry.

Key Components:

1) Lift reduced-order models to a common design tradespace, then use Pareto optimization to navigate that tradespace.

2) Decompose NLP optimization problem into sequence of QCQP subproblems for efficiency

Multi-behavior optimization: Optimized multi-template design requires less effort for both locomotion and manipulation and Pareto-dominates nominal design for both behaviors.



Decomposed Optimization: Break apart full NLP into three subproblems then solve iteratively:

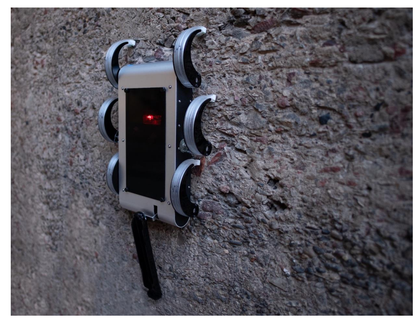
1) Design parameters (e.g. link lengths)
2) Configuration parameters (e.g. joint angles)
3) Dynamic consistency (e.g. contact forces)

Each can be a QCQP, as kinematics are quadratic in either design OR (transformed) configuration. Result is twice as fast as full problem.

Broader Impact: Design for multibehaviorality will help produce e.g. home assistance robots that must move and interact in human environments.

Education: Tools and examples from this project were incorporated into multiple classes. Tutorial article to be submitted soon.

REU: Undergraduate project to build legs that are good at both running and climbing by optimizing material properties and dimensions.



Outreach: Hosted afterschool program for middle schoolers teaching CAD (virtually in pandemic) and building small legged robots.