# Enabling Self-Sufficient Robot Learning

**Rika Antonova** — NSF/CRA Computing Innovation fellow; postdoctoral scholar

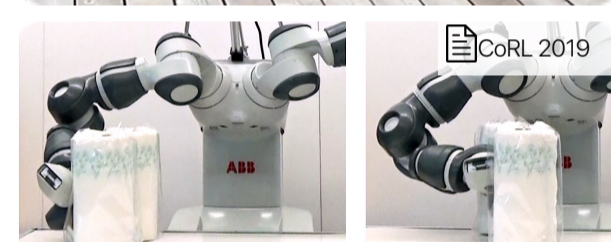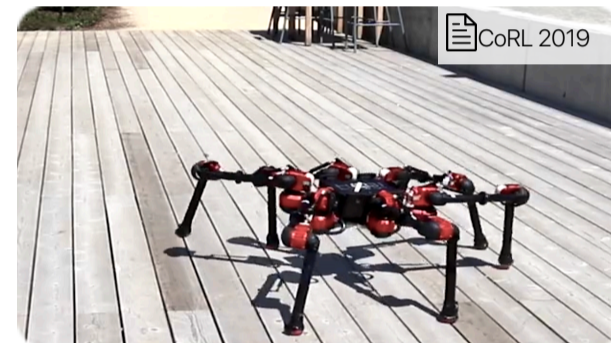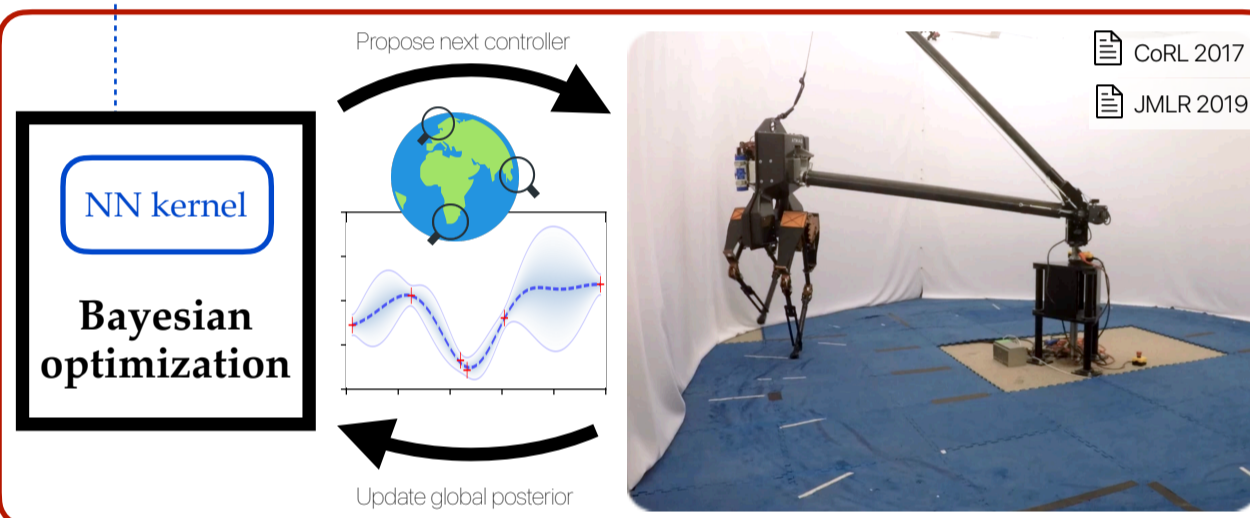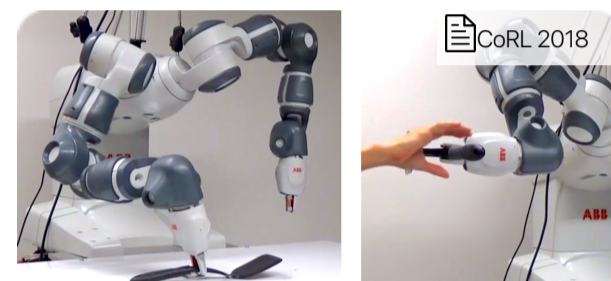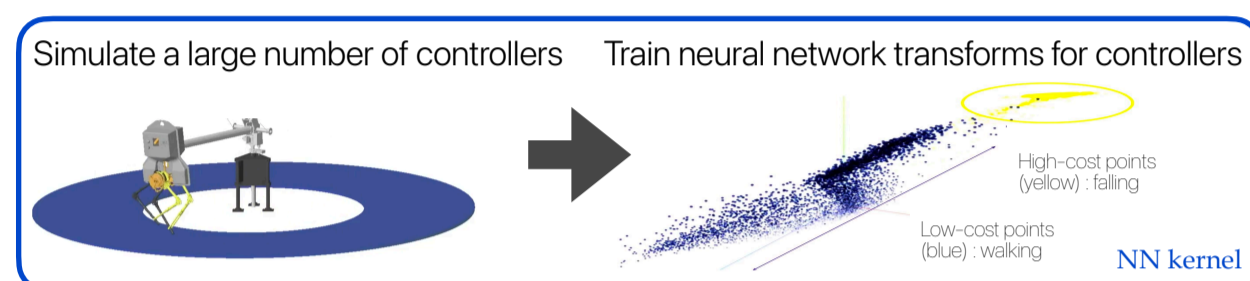**Stanford University**

## Research areas

- Bayesian methods for active global exploration & reinforcement learning
- Ultra data-efficient sim-to-real transfer
- Real-to-sim for scalable simulations
- Mobile manipulation with deformables

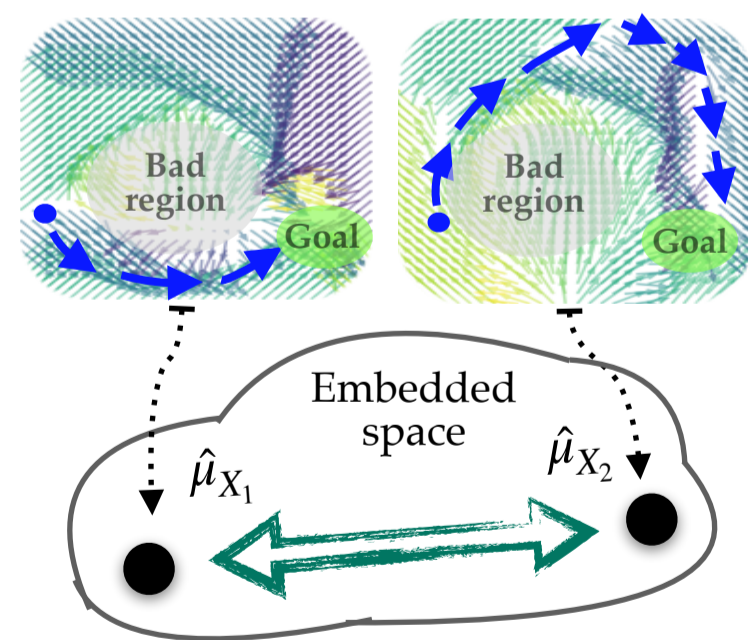## Active global exploration & reinforcement learning in unstructured environments

### Past work

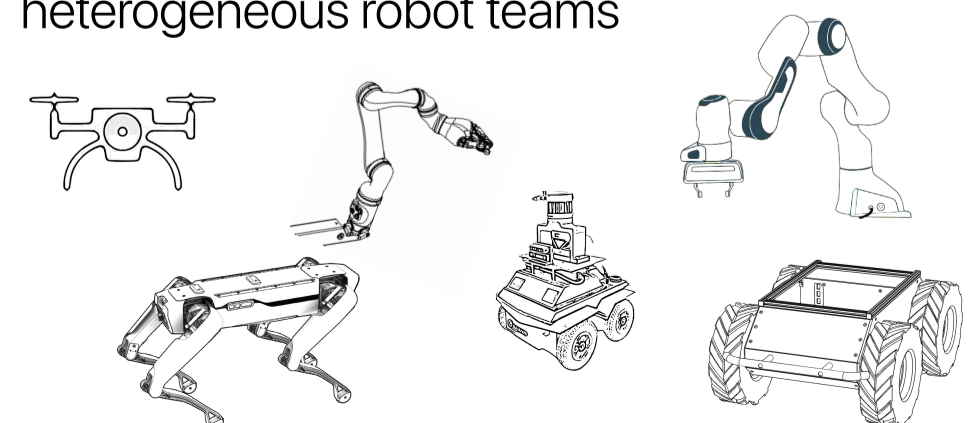#### Bayesian optimization with simulation-informed kernels



Simulate a large number of controllers → Train neural network transforms for controllers

High-cost points (yellow) : falling
Low-cost points (blue) : walking
NN kernel

Propose next controller
NN kernel
**Bayesian optimization**
Update global posterior

CoRL 2017
JMLR 2019
CoRL 2018
CoRL 2019
CoRL 2019

### Future plans

#### Global policy optimization in function spaces



Bad region — Goal
Bad region — Goal
Embedded space $\hat{\mu}_{X_1}$ $\hat{\mu}_{X_2}$
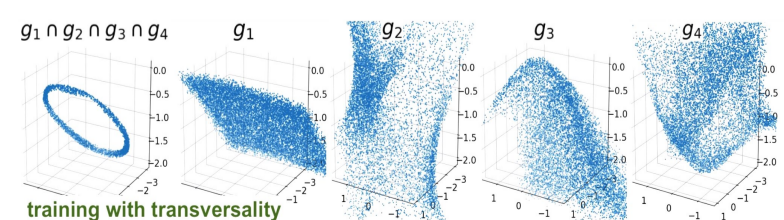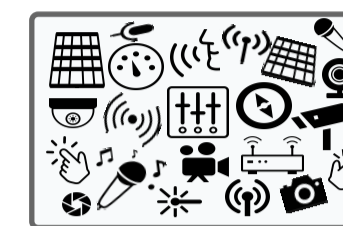
- Learn distribution embeddings for RL policies
- Extend our *Analytic Manifold Learning* work ( learning independent relations ) to discover diverse sets of policies
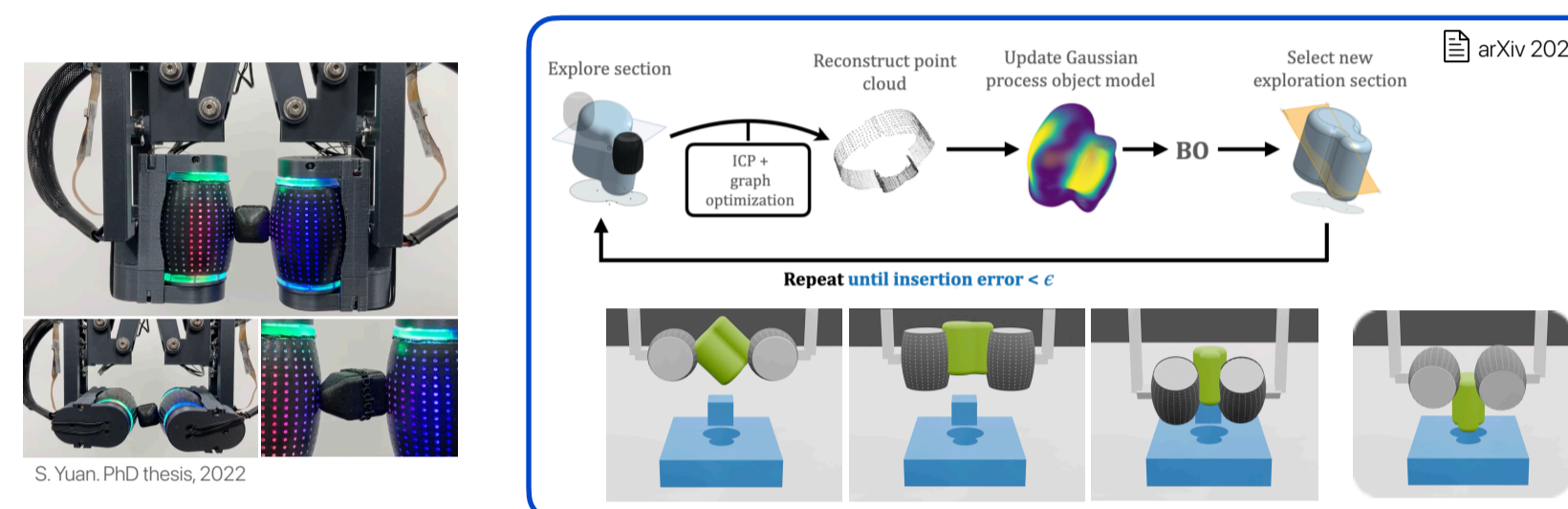
$g_1 \cap g_2 \cap g_3 \cap g_4$  $g_2$  $g_3$  $g_4$
training with transversality

- mobile manipulation with deformables
- heterogeneous robot teams

## Learning to be multimodal : co-design of sensing and machine learning methods

### Past work

#### Exploring the potential of recently proposed sensors



S. Yuan. PhD thesis, 2022

Explore section → Reconstruct point cloud → Update Gaussian process object model → Select new exploration section
ICP + graph optimization → BO
Repeat until insertion error < ε
arXiv 2023

#### Comparing effects of high- vs low-resolution sensing



RealSense  Photoneo  RealSense  Photoneo  Photoneo  Photoneo

### Future plans



**Novel simulated sensors**
High-fidelity spectrometer
Super-resolution skin
Broad-spectrum vision
Night vision  Low-inertia touch

*Evolve design for promising sensors*

**Global search for optimal sensing**

**Optimize policies for target tasks**

**Advanced real sensors**
High-speed RGB  High-quality sound
High-coverage skin  Ultrasound
High-speed depth  High-speed tactile
Wifi & radio to 'see through walls'

- Sample a batch of sensor modalities & properties $\{\boldsymbol{x}_1^{(n)}, ..., \boldsymbol{x}_C^{(n)}\}_{n=1}^{N}$
  e.g. low-resolution vision, high-resolution tactile
- Train to solve a set of target tasks
- Infer combo utility from task performance & update global posterior

## Autonomy at the next level

### Neuromorphic Bayesian optimization for resource-constrained hardware



**BO-SSP**  VSA vector decomposed  Multi-agent trajectory  Environment
$\phi(\mathbf{x}_t)$ decode  $\mathbf{x}_t$ execute
High-dim VSA vector
Spatial Semantic Pointer Bayesian Optimization
$f(\mathbf{x}_t)$ reward
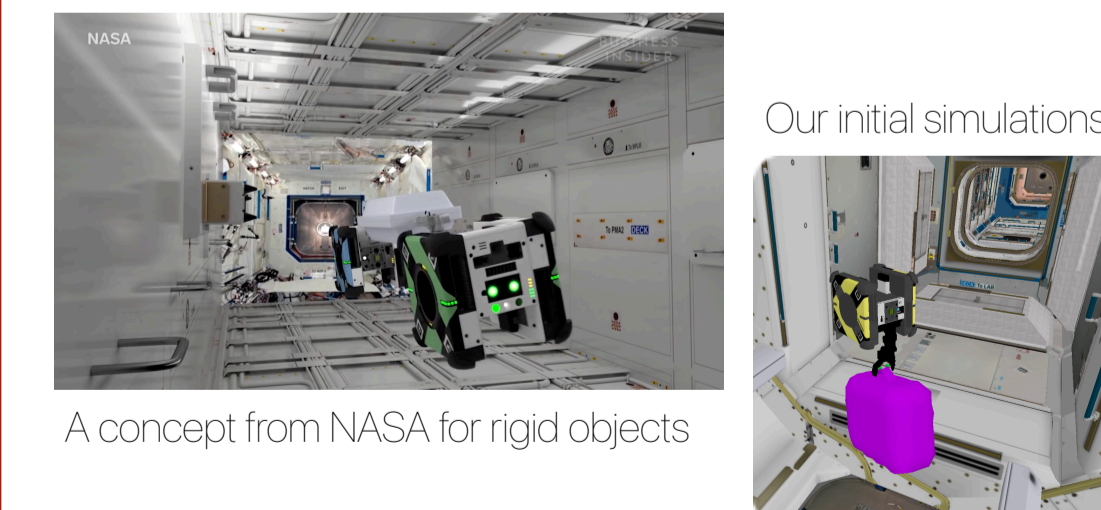Hexagonal basis  $\phi^*$ convex optimization
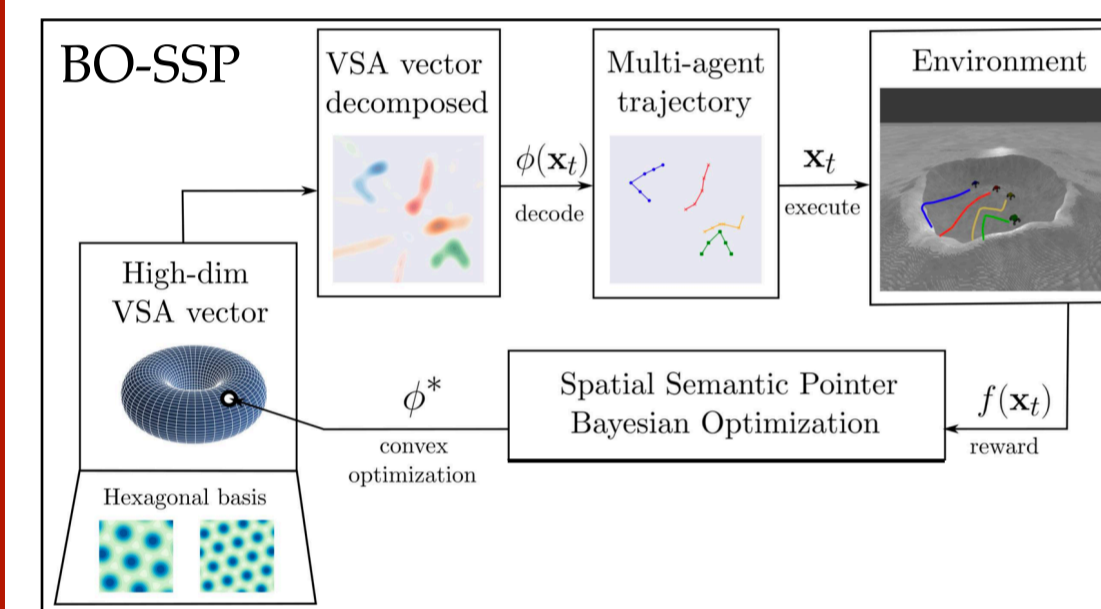
Goal: enable long-term autonomous missions with low-power and low-memory consumption
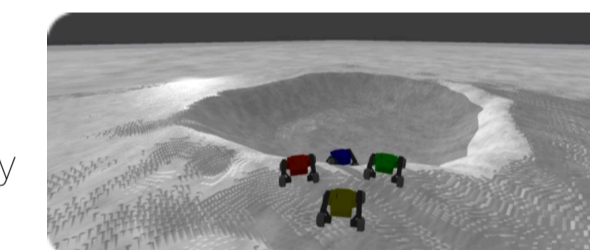
*Collaboration with the University of Waterloo*

### Transporting deformable cargo bags with Astrobee robots



A concept from NASA for rigid objects

Our initial simulations

Goal: assess feasibility of transporting deformable cargo bags

*Collaboration with the NASA Astrobee team*