GIRAF: Greatly Increased Reach for Adaptive Fieldwork

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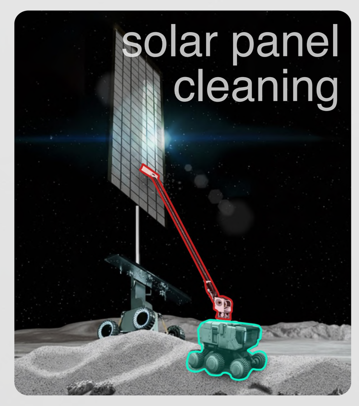
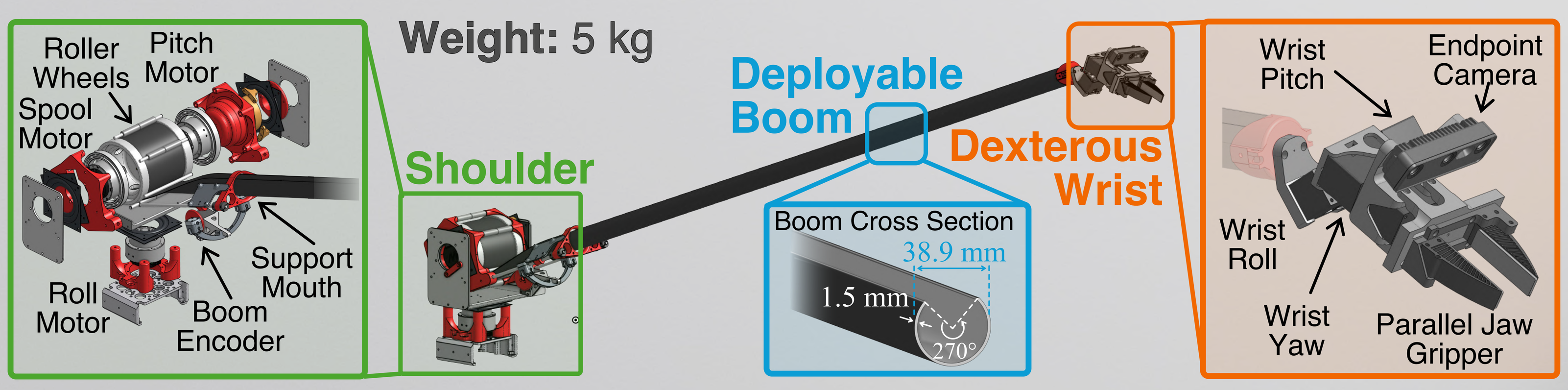
Introduction

Future field and lunar infrastructure will require robots to work across spaces far larger than themselves [1]. We propose **GIRAF**, which augments a legged mobile robot with a **long-reach, lightweight deployable manipulator** for tasks across large workspaces.



Deployable Boom Manipulator

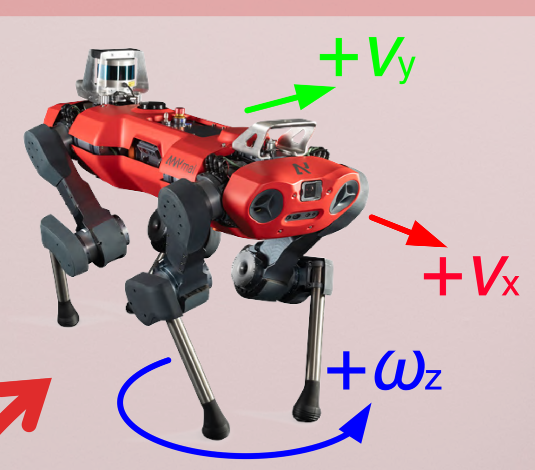
We use a slit-tube rollable fiberglass boom structure (3m long) [2]. The manipulator has a 3 DoF base (Roll, Pitch, Extension) and a dexterous 3 DoF wrist at the endpoint. An endpoint camera is used with visual servoing for accurate task localization and position control.

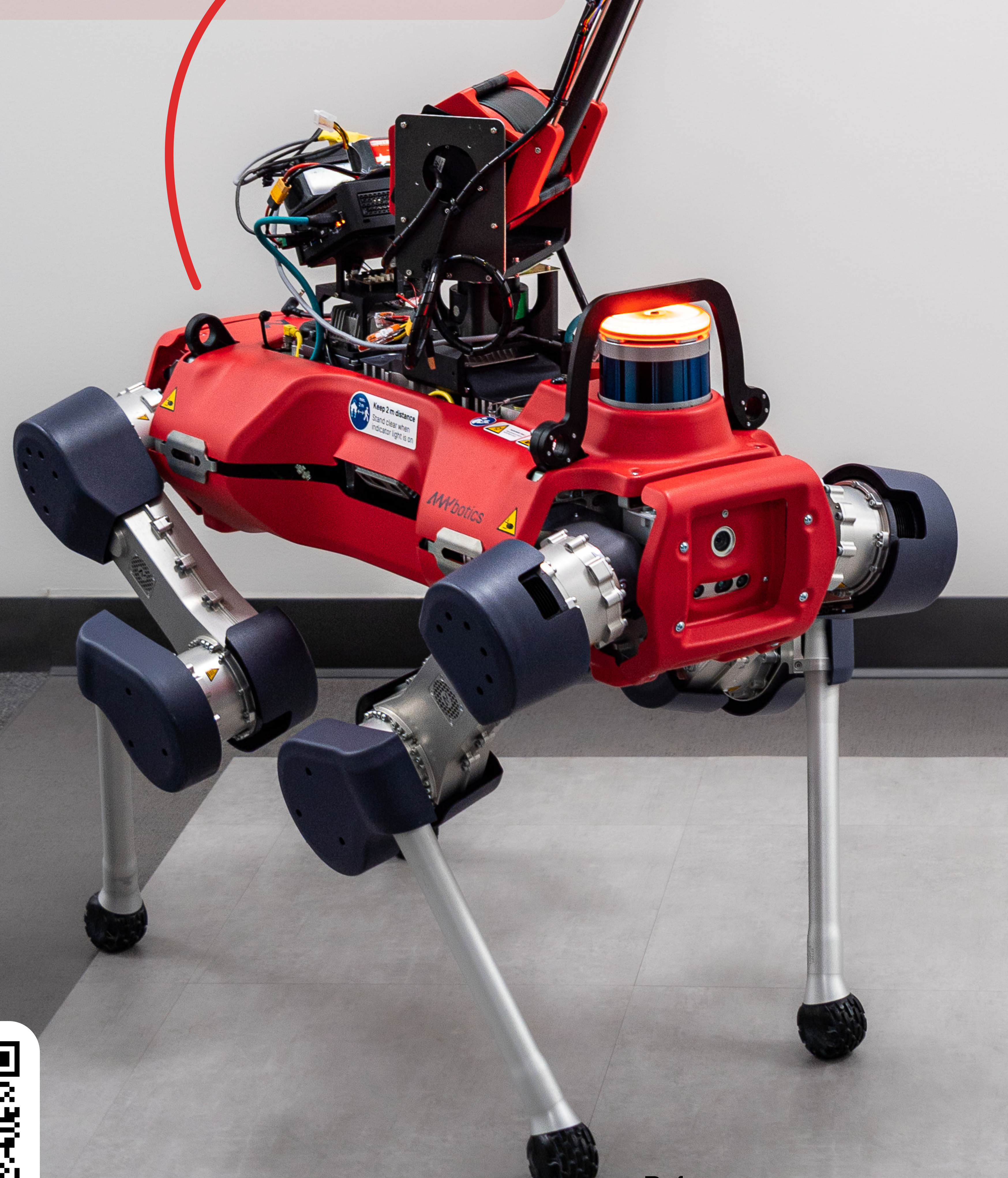


ANYmal D Mobile Base

The mobile base is an ANYmal D legged robot, with accurate omnidirectional movement and mobility in sloped and uneven terrains.

Weight: 50 kg
Max Payload: < 15 kg



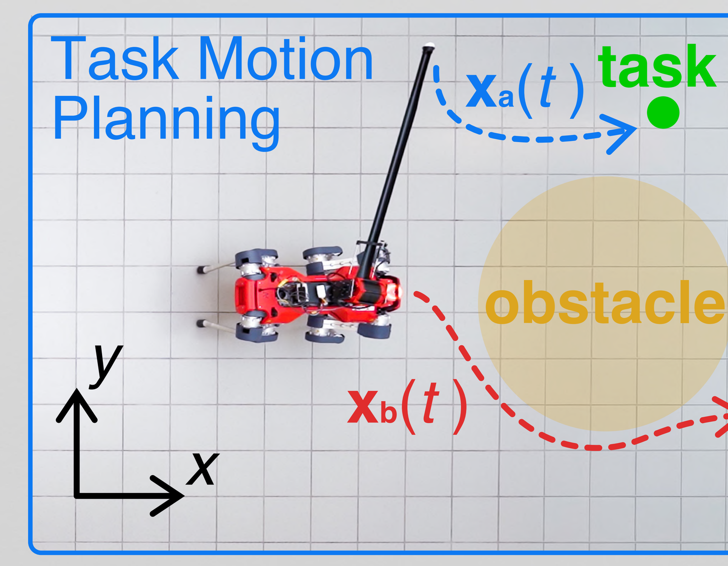


Manipulation Tasks

High Workspace Cable Outfitting | Delicate Surface Cleaning | Precision Assembly

Trajectory Planning

Sequential trajectories are planned for both the mobile base (x_b) and long reach manipulator end-effector (x_a) to reach target task points (x_t) while avoiding workspace obstacles (x_o).

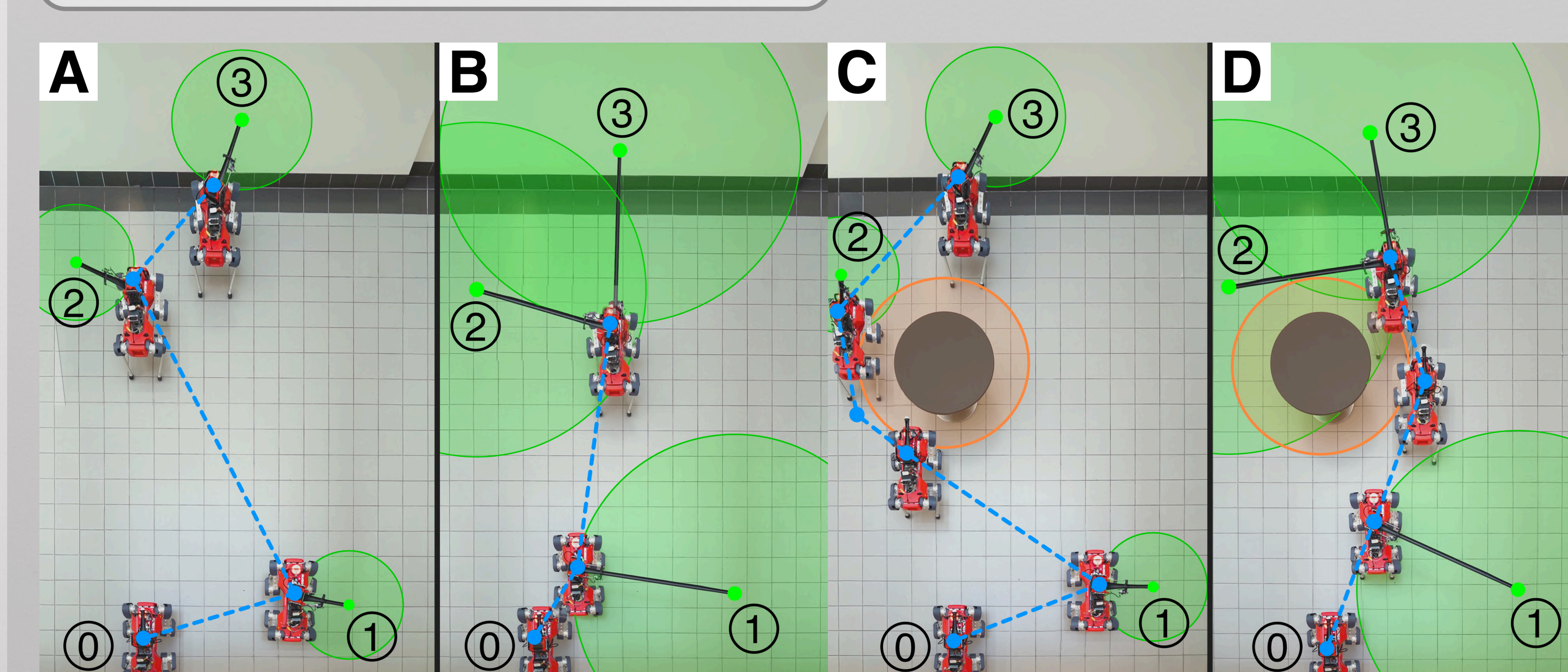


$$\min_{X} \sum_{i=1}^{N-1} \|\mathbf{x}_{i+1} - \mathbf{x}_i\|_2$$

$$\text{s.t. } \|\mathbf{x}_{b1} - \mathbf{x}_{t1}\|_2 \le r_{t1}$$
$$\|\mathbf{x}_{b2} - \mathbf{x}_{t2}\|_2 \le r_{t2}$$
$$\|\mathbf{x}_{b3} - \mathbf{x}_{t3}\|_2 \le r_{t3}$$
$$\|\mathbf{x}_i - \mathbf{x}_o\|_2 \ge r_o \quad i = 1, \dots, N$$

$\mathbf{x}_{t1} = [0.5, -2.0]$ m $\mathbf{x}_{t2} = [3.5, 1.0]$ m
$\mathbf{x}_{t3} = [5.0, -0.5]$ m $\mathbf{x}_o = [3.0, 0.0]$ m

A minimum distance problem formulation is used to select polyline waypoints satisfying both task reachability and obstacle constraints. Trajectories are solved in CVXPY w/ DCCP, then deployed on hardware experiments shown below



Hardware experiments w/ long reach (B, D) vs. short (A, C)

Experiment	Reach Limit	Obstacle	Distance	Time
A	0.5 m	no	6.5 m	48 sec
B	2.0 m	no	3.3 m	67 sec
C	0.5 m	yes	7.5 m	60 sec
D	2.0 m	yes	4.2 m	73 sec

Future Work

Integrated field manipulation with GIRAF in NASA-relevant lunar test environments, demonstrating vision-informed grasping and assembly.

Refined planning and control to coordinate base motion, long-reach arm stability, and task accuracy for more complex risk-aware environments.

Website QR

References:
[1] W. K. Belvin, W. R. Doggett, J. J. Watson, J. T. Dorsey, J. E. Warren, T. C. Jones, E. E. Komendera, T. Mann, and L. M. Bowman, "In- space structural assembly: Applications and technology," in *3rd AIAA Spacecraft Structures Conference*, 2016, p. 2163.
[2] S. Wang, V. Kojouharov, L. Y. Chung, D. Morton, and M. Cutkosky, "Long-reach robotic manipulation for assembly and outfitting of lunar structures." *2025 International Conference on Space Robotics (iSpaRo)*. IEEE, 2025.