Overview of ongoing projects

--Soham Kulkarni

Project 1: Sarathi: A multimodal modular robotics platform

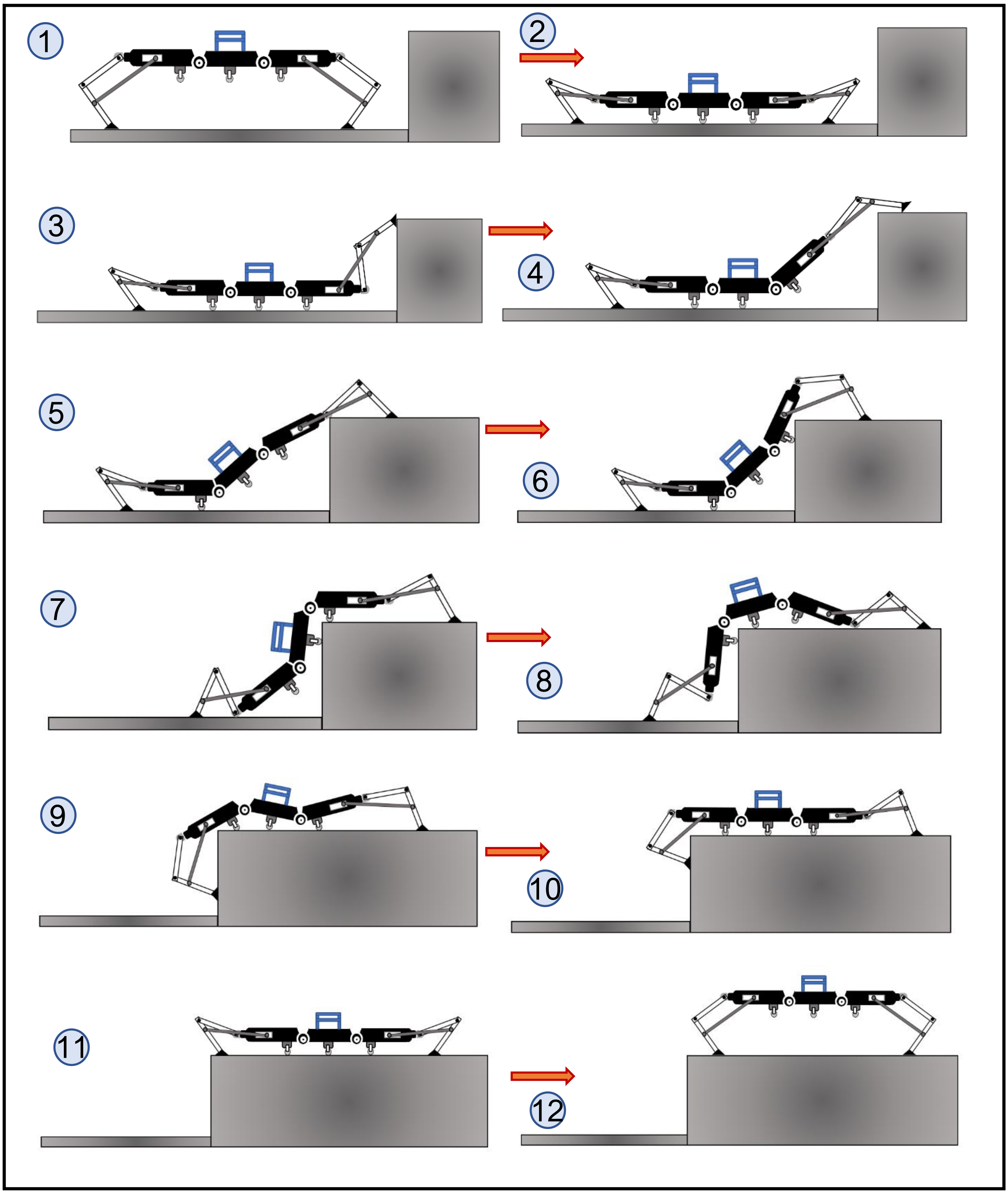


Fig. 1. Demonstration of series of steps executed by the robot to perform a climbing task (obstacle height is great than robot height), note that this is not a complete dynamical abstraction, its more of an anchor[1] model

References: [1] Full, Robert & Koditschek, Daniel. (2000). Templates and Anchors: Neuromechanical Hypotheses of Legged Locomotion on Land. The Journal of experimental biology. 202. 3325-32.

Robot unit description

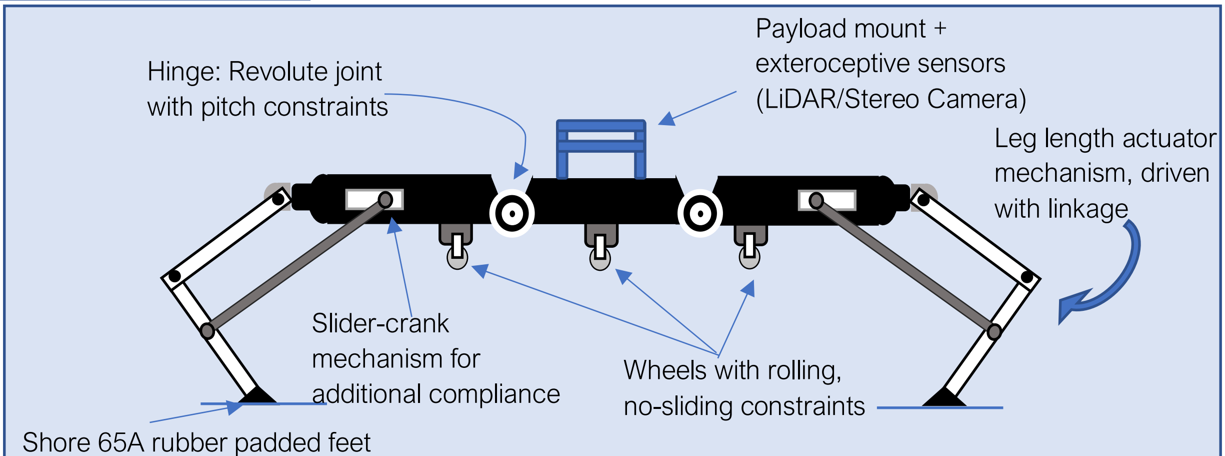


Fig.2. Sagittal Plane view of the robot

Objective

The robot is designed to achieve certain **locomotion objectives** mentioned below efficiently:

- Crossing an obstacle whose height is greater than the maximum achievable heigh of the robot. The detailed plan is shown in fig. 1.
- Travelling through narrow gaps (like that of between two closely packed walls)
- Travelling down through a tunnel / low level area

  Additionally, there is a payload mount on the middle link (max. capacity not calculated yet), and multiple such unit systems can be combined to work synchronously (future aspects).

By tweaking this design, I have thought about several other design alternatives as well.

Work done

I've started working on this project last month. I've started working on the actuator testing and leg fabrication.

Targeted Applications

The targeted applications for the project are: Security Surveillance, ground control and inspection.

Work to do: Important questions (in ascending order of work levels)

1. For the robot model mentioned above, choosing the locomotion model of the system; considering it as an optimal control problem is crucial. Approximating the Whole-body dynamical system to reduced order models (or templates for the anchor models) like LIPM (Linear Inverted Pendulum Mode), SLIP (Spring Loaded Inverted Pendulum), Capture point dynamics, Centroidal dynamics, etc. would not account for some whole-body constraints for complex systems and would give sub-optimal solutions.

   I was looking up for centroidal dynamics abstraction for our system so as to reduce the centroidal state estimation errors and ensuring dynamical consistency for the motion planning problem.

Is there any optimal solution in between these extremities that would account for these constraints and be computationally feasible in terms of complexity of the model?
Problems: Balancing, avoiding collisions, counteracting external disturbances, etc.

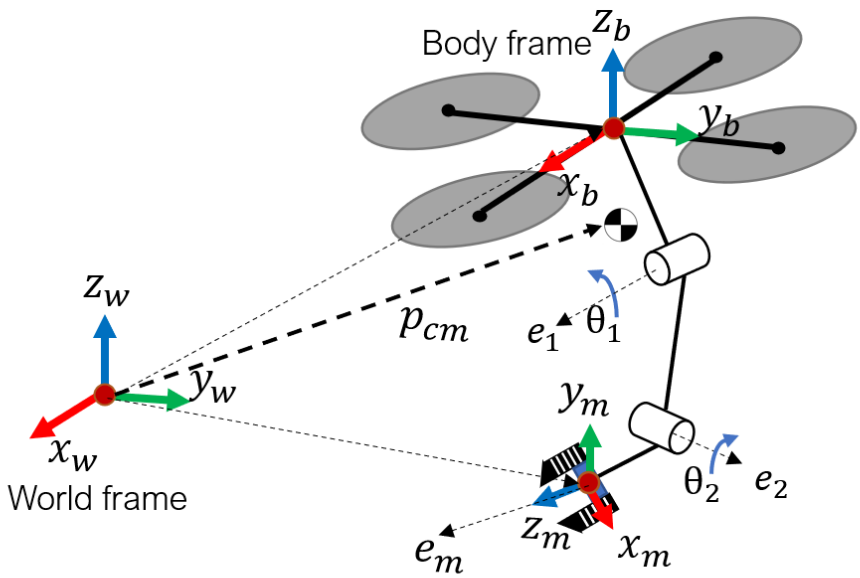
2. Taking this one step further, another crucial problem is motion generation using MPC (Model Predictive Control) based controllers (considering simplified dynamics and terrain constraints). Can we design a robust predictive controller to optimize gait cycles, foot placements, gait cycles, CoM trajectories and additionally CoT?
   I was also looking up for Neural nets based (trained in simulation) and Reinforcement Learning (model-free) based controllers serving different purposes.
   The robot URDF (Universal Robot Description Format) model can be imported to the simulation interfaces (Gazebo 9 for simulating environment, and rViz for simulating sensor data, many other alternatives available) .

3. Sim2Real problems to overcome the 'reality gap'

4. Further: Perception, state estimation (using UKF for multi-sensor fusion of the proprioceptive sensor data: IMUs, joint encoders, etc.), Simultaneous Localization and mapping (SLAM),
   (Not using LiDARs here due to loop closure problems and identification of semi-transparent objects)

   There are yet a lot of things left out in the background here…a lot of questions yet to be explored.

Project 2: Aerial Manipulator



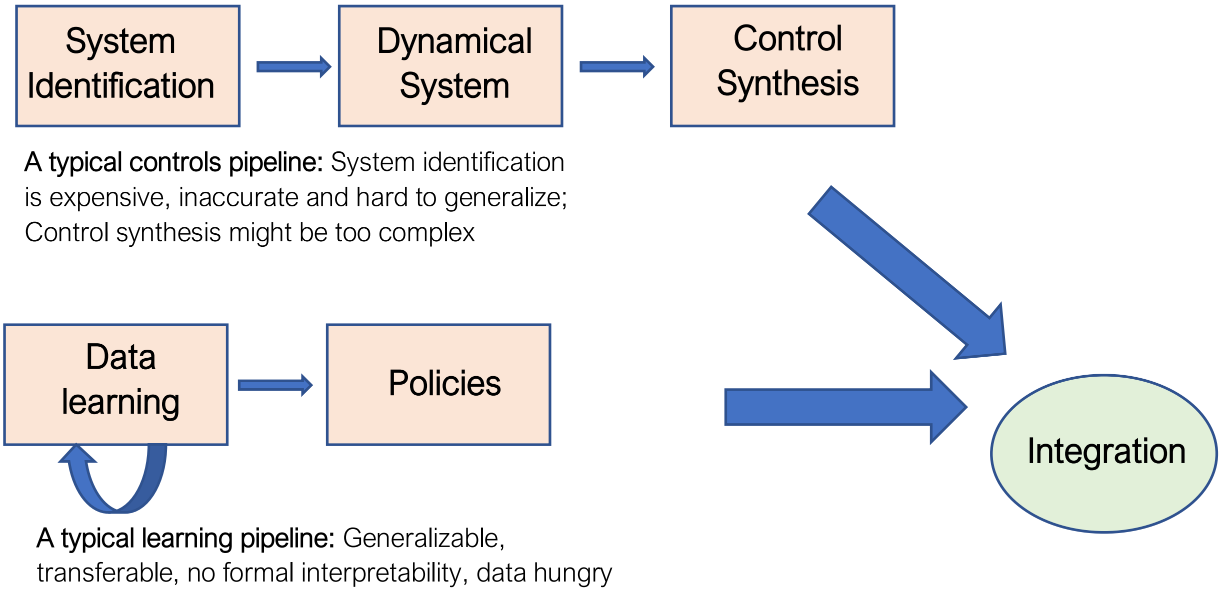
Aerial Manipulator schematic

Objective

The main objective is to bring the robustness and dexterity of fixed end manipulators to aerial platforms.

Work to do: Important questions

There has been some good work published on this lately, especially in this recent ICRA 2021, for e.g. [2] shows a control framework for an aerial manipulator to push various types of physical structures without prior knowledge of its physical parameters, [3] shows a fully-actuated platform for contact-based inspection and [4] shows work on finding dynamically feasible system trajectories that also achieves desired end-effector motions. This can be implemented on a standard quadrotor platform.



References:

[2] D. Lee, H. Seo, I. Jang, S. J. Lee and H. J. Kim, "Aerial Manipulator Pushing a Movable Structure Using a DOB-Based Robust Controller," in IEEE Robotics and Automation Letters, vol. 6, no. 2, pp. 723-730, April 2021, doi: 10.1109/LRA.2020.3047779.

[3] Karen Bodie, Maximilian Brunner, Michael Pantic, Stefan Walser, Patrick Pfändler, Ueli Angst, Roland Siegwart, Juan Nieto, "An Omnidirectional Aerial Manipulation Platform for Contact-Based Inspection", DOI: https://doi.org/10.3929/ethz-b-000382037

[4] J. Welde, J. Paulos and V. Kumar, "Dynamically Feasible Task Space Planning for Underactuated Aerial Manipulators," in IEEE Robotics and Automation Letters, vol. 6, no. 2, pp. 3232-3239, April 2021, doi: 10.1109/LRA.2021.3051572.

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