Minimalistic Bio-Inspired Brachiation Robots

Mahdi Javadi*, Shourie S. Grama, Daniel Pizzutilo and Shivesh Kumar
Robotics Innovation Center, DFKI GmbH, 28359 Bremen, Germany, email: firstname.lastname@dfki.de

I. Introduction

Dynamic mobile robots gained significant attention in recent years and have demonstrated robustness in performing agile maneuvers and tackling complex tasks. Examples such as parkour capabilities with Atlas biped robot by Boston Dynamics [1] and ANYmal quadruped by ETH Zurich [2], the superhuman performance of autonomous drones as demonstrated in the work of Song et al. [3] highlight the advancements in mobile robotics. Among the diverse fields of robotics and locomotion modes, bio-inspired brachiation robots have not received the desired level of attention. To investigate this complex mode of locomotion, there is a necessity for minimalist, modular, and cost-effective brachiation robots. This paper presents two unconventional open-source canonical brachiation robots, AcroMonk [4] and RicMonk [5], that can perform multiple brachiation maneuvers with their passive grippers.

The first brachiation robot was introduced in the 1990s by Fukuda et. al [6] and the majority of the studies in this area focused on active grippers [7], which are prone to complexity and errors if gripper malfunctions. In real-case scenarios, active grippers offer enhanced adaptability in managing diverse contact points, such as rigid, soft, and unstructured handholds [8]. However, active grippers introduce complexity when investigating such systems in a basic research. AcroMonk and RicMonk, characterized by their innovative design and passive grippers, are specifically designed for fundamental research on underactuation robotics and minimal setup contact scenarios.

AcroMonk stands as the pioneering two-link underactuated brachiation robot, that could perform robust forward brachiation maneuvers with passive grippers. Minimality, reproducibility, modularity and portability were primary criteria for the design of the AcroMonk, known as the simplest possible brachiation robot with only one Quasi-Direct-Drive (QDD). To address the discrepancy between simulated and real-world environments, the passive gripper was innovatively designed with a region of attraction, enabling the robot to effectively grasp the bar despite inaccuracies in the controllers. A robust forward brachiation on a horizontally-laid ladder with uniform bar distance with model-free and model-based controllers together with a reinforcement learning-based control policy is demonstrated in the experimental setup. AcroMonk is not able to perform backward brachiation robustly, primarily due to its limitations posed by single-actuator design.

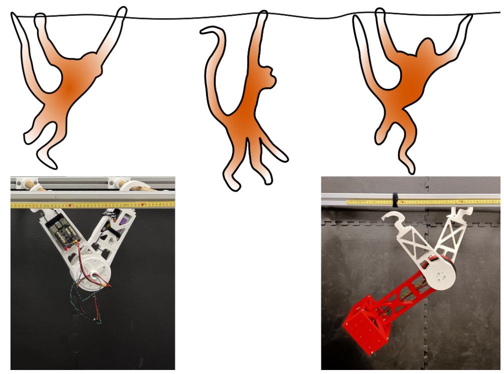

Fig. 1. Bio-inspired brachiation robots, AcroMonk and RicMonk

RicMonk, the successor of AcroMonk, is the first three-link underactuated brachiation robot that could perform bi-directional brachiation maneuvers with passive grippers. The robot includes two QDDs interconnected by a tail, resembling the body of a monkey, which aids in building momentum for highly dynamic maneuvers, such as ricocheting. This enabled RicMonk to independently move its arms and robustly attach and detach in both directions, facilitating multiple bi-directional brachiation maneuvers. The Cost of Transport (CoT), a dimensionless metric, serves as a measure of energy efficiency and facilitates comparison across varying weights and sizes. A comparative analysis between these brachiators is presented in [5] with CoT of 0.3355 and 0.276 for AcroMonk and RicMonk respectively, demonstrating that integrating the body into RicMonk enhances energy efficiency.

II. Discussion and Conclusion

Future challenges include addressing the irregular ladder environment, online trajectory generation, and incorporating contact into trajectory optimization. Moreover, a universal gripper design capable of making and breaking contact to deal with a variety of handholds is essential for deploying the robot in real-world scenarios, such as search and rescue missions. These prototypes represent the initial iterations of underactuated brachiation robots equipped with passive grippers, intended for research purposes, and made available as open-source resources. Achieving insights into robust brachiation performance could pave the way for the development of multi-locomotion robots capable of executing bipedal, quadrupedal, brachiation, and morphing maneuvers, incorporating propellers for diverse locomotion scenarios.

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