Development of a Bipedal Hopping Robot With Morphable Inertial Tail for Agile Locomotion*

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I. Introduction

Animals often use their external appendages (such as tails, limbs) to achieve spectacular maneuverability, energy efficient locomotion, and robust stabilization to large perturbations, which may not be easily attained in the existing legged robots. Their appendages, particularly, the tails are very compact, light, highly dexterous with a large range of motion (ROM). Animals can also curl and straighten up their tails in less than one-tenth of a second to facilitate rapid adjustment for the moment of inertia (IoM) and the Center of Mass (CoM) [1]. Most of the existing robotic tail designs still lack dexterity, output force, dynamic response as compared to their biological counterparts. The objective of this research is to create a viable and compact tail solution capable of adjusting the tail IoM effectively for the enhancement of robot agility. The proposed tail solution has also been incorporated with our two-legged hopping robotic platform (Fig. 1) for performance verification.

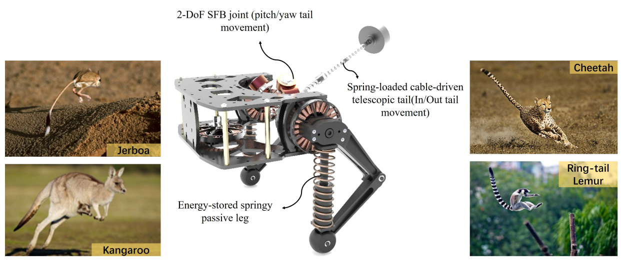

Fig. 1: Overall design of the proposed tail-inspired hopping robotic platform.

II. Robot Design and Controller

We propose a novel, 3-DoF robotic tail mechanism that comprises a Proximal Tail Component (PTC) and a Distal Tail Component (DTC). The PTC consists of a Spherical Parallel Bar (SFB) mechanism (Fig. 2(a)) to provide responsive and precise pitch-yaw motions necessary for the reaction torque generation, while the DTC formed by a spring-loaded telescopic tail to facilitate rapid tail "extension/retraction" (Fig. 2(b)). A universal pulley system is specially designed to regulate the cable direction to enhance smooth SLTT retraction and release even if the tail changes its orientation with SFB. As a result, the pitch-yaw and "extension/retraction" motions are decoupled. In our bipedal hopping robotic platform, the leg is controlled indirectly by the swinging tail through the reaction torque. An energy-stored compliant springy leg based on a 4-bar-linkage design is developed. The overall physical implementation is shown in Fig. 2(c), a dynamic model [2] and propose motion controllers [3] are developed for tail-inspired locomotion (Fig. 2(d)).

III. Initial Experiments AND Future Work

We conducted experiments to evaluate the proposed robotic tail design and the overall system performance. A benchtop experimental study was performed to investigate the performance of a stand-alone 3-DoF morphable inertial tail (Fig.3(a)). We also performed an overall system hopping test in a 2D sagittal plane to understand the tail's capability on body orientation control and tail-energized hopping motion (Fig.3(b)). Meanwhile, we verified the existing actuators and 2-DoF SFB structure that have enough torque capability in supporting Body-Tail Stabilization of the entire body and more details can be found in [4]. Besides, we developed some advanced control strategies to enhance extreme manuevers such as tail-inspired turn (Fig.3(c)) or forward somersault (Fig.3(d)) to demonstrate the advantages of having an external appendage in locomotion. It is our hope to develop robotic systems capable of performing the extreme locomotion manuevers with ease.

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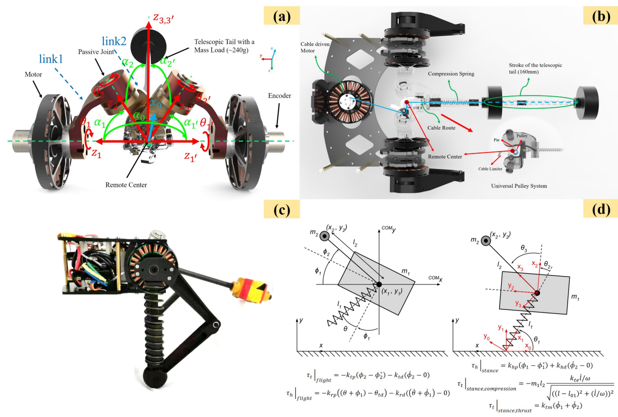

Fig. 2: (a) 2-DoF SFB Joint (Pitch/Yaw Movement of the Tail); (b) Spring loaded, cable driven telescopic tail; (c) Initial robot prototype; (d) 2-DoF tailed robot model and controller.

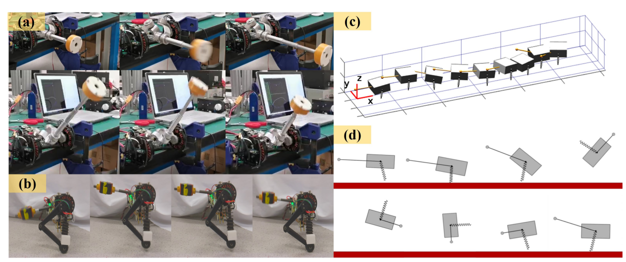

Fig. 3: (a) Snapshots of the morphable inertial tail in 3D motion; (b) Snapshots of the robot hopping continuously in the sagittal plane; (c) Simulation results of 3D continuous tail-energized hopping and turning; (d) Simulation results of forward somersault with tail retraction and extension.

References

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