**Design and Control of Bioinspired Articulated Robotic Tails for Stabilization and Maneuvering of Legged Robots**

Extended Abstract

Traditionally, high-performing legged robots require complex spatial leg designs and controllers to simultaneously implement propulsion, maneuvering and stabilization behaviors during operation. However, in nature, animals utilize tails either in place of legs or to enhance their legs' capabilities. Furthermore, looking to the biological structure of various animal tails, a clear connection can be made between their topologies and the topology of continuum and serpentine articulated robots. A key point of emphasis in Virginia Tech's Robotics and Mechatronics Lab over the past several years has been to innovate new designs of continuum and serpentine robots that meet the requirements for a robotic tail.

Four key requirements of a robotic tail include: (1) multi-functionality, to act in multiple spatial directions, (2) high-speed motion, to generate rapid dynamic impulses in addition to the shifts in gravitational loading as the tail reconfigures, (3) cantilevered operation, to actively or passively resist sag when extended, and (4) scalability, to enable a variety of lengths, mass distributions and number of actuated segments.

Three designs that meet these criteria have been conceptualized, optimized and implemented experimentally: the Universal-Spatial Robotic Tail (USRT), the Roll-Revolute-Revolute Robotic Tail (R3RT), and the Discrete Modular Robotic Tail (DMST). These three designs implement both rigid coupling between the links in a segment (R3RT, DMST), as well as elastic coupling between segments (USRT). Furthermore, each tail design is capable of spatial motion: the USRT due to its composition as a serial chain of universal joints, and the R3RT and DMST due to the roll-degree-of-freedom at each tail's base. In addition, to aid in the optimization of the designs and to help predict the forces and moments a given tail is capable of generating, kinematic and dynamic models of each of the tail designs have been formulated.

In terms of tail control, to implement the desired maneuvering and stabilizing behaviors, outer- and inner-loop controllers are formulated for the serpentine tails: the outer-loop controllers generate the desired tail trajectory to maneuver or stabilize the legged robot, and the inner-loop controllers calculate control inputs for the tail that implement the desired tail trajectory using feedback linearization. Maneuvering and stabilizing case studies are generated to demonstrate the tails' ability to: (1) generate yaw angle turning in both a quadruped and a biped, (2) improve the quadruped's ability to reject an externally applied roll moment disturbance that would otherwise destabilize it, and (3) counteract the biped's roll angle instability when it lifts one of its legs (for example, during its gait cycle).

Tail simulations and experimental results are used to implement these case studies in conjunction with multi-body dynamic simulations of the quadrupedal and bipedal legged platforms. Results successfully demonstrate the tails' ability to maneuver and stabilize legged robots, and provide a firm foundation for future work implementing a tailed-legged robot.