Design, Modeling, Learning-based Control of Super-Coiled Polymer Actuated Bio-inspired Robots

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Abstract: Bio-inspired robotics takes advantage of biological systems in nature for morphology, action, and perception to build advanced robots of compelling performance in versatile applications. A rapidly progressing branch of bio-inspired robotics – soft robotics, has gained significant scientific attention in recent years. Employing the use of flexible materials and soft actuators such as artificial muscles in the construction of soft robots, contributes to a substantial increase in the mimicry of biological functions and locomotory bio-mechanisms. Super-coiled polymer (SCP), a newly-developed type of artificial muscles comparatively offers many advantages in terms of cost, size, flexibility, fabrication, and power-to-weight ratio, potentially making SCPs a great fit for deployment in bio-inspired robots. Development of such biomimetic designs incorporating artificial muscles, increasingly necessitates derivation of precise dynamic models for motion prediction and controller design. Nevertheless, the process of modeling the system dynamics of such sophisticatedly evolving robots becomes difficult due to their continuum dynamics and high dimensionality. To address the problems of high nonlinearity and intrinsically infinite system dimension, contemporary artificial intelligence techniques, specifically reinforcement learning algorithms, are employed to design learning-based controllers. This necessity of developing intelligent control serves as the motivation to not only mimic the bio-mechanisms, but also mimic the cognitive abilities of these biological life forms, which is where learning-based controllers will play a major role in such bio-inspired robotic systems. Our research aims at designing and developing two motivating SCP-driven bio-inspired robots: 1. Robotic eye and 2. Soft robotic fish, modeling their system dynamics, and developing robust learning-based controllers to achieve various objectives pertaining to locomotion, localization, perceptive control, etc. Our proposed learning-based control design employs the use of deep-deterministic policy gradient (DDPG) reinforcement learning algorithm to train the agent with a linear quadratic regulator (LQR) based multi-objective reward. The effectiveness of the proposed control method was verified through simulations for both robotic eye and fish platforms. This topic is collaboratively researched under the advice of Dr. Ningshi Yao and Dr. Feitian Zhang.