Snake robot locomotion with compliant elements

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Abstract

Snake robots can be at the same time efficient tools to answer questions coming from biology on animal locomotion, but also agile machines that are able to efficiently locomote over unstructured terrains and narrow spaces, useful for engineering problems such as search and rescue. Compliance in the snake robot structure could bring many advantages such as faster locomotion speed, higher energy efficiency (e.g. by using the compliant elements to store and release elastic energy), reduced shock loads on the robot and its actuators, and improved terrain handling capabilities (e.g. for crossing features that offer fewer points of contact, such as moving along cylindrical pipes), compared to having completely rigid body and actuators. Other authors have started exploring the use of impedance/torque control strategies in stiff snake robots [1] [2], or including series elastic [3] [4] or variable stiffness actuators [5].

In our work we are exploring the benefits of adding in-series passive compliance in a homogeneous modular snake robot to see if passive compliance alone can provide some of the aforementioned advantages. For this reason, we created virtual and hardware implementations of an 8-DoF Lola-OP™ Modular Snake Robot [6] with added in-series compliant elements (Fig. 1, top) and analyzed their behavior for two types of gaits (i.e. rolling and sidewinding) on different terrains as a function of the stiffness value of the compliant elements. The 8-DoF Lola-OP™ Modular Snake Robot is composed of eight 1-DoF modules connected to each other with a twist shift of 90° on their rotating axes. Between these modules we added cylindrical compliant beams with different levels of stiffness. We performed grid search and used optimization techniques to find efficient control parameters that lead to high locomotion speed in simulation. We are currently in the process of validating simulation results using the hardware robot.

For the rolling gait (Fig. 1, bottom) we noticed a general trend of faster locomotion speed for stiffer robots controlled with small amplitudes. For sidewinding there is a plateau, with an almost flat speed profile over a large range of stiffness values. Although we did not observe a clear optimal level of compliance, it is still interesting to note that relatively soft robots can locomote with a speed similar to stiffer ones. Clearly there is a lower bound of stiffness level after which the robot is too compliant and its locomotion is ineffective. Many research questions are yet to be answered and discussed in order to understand why animals are partially compliant when they locomote and what is their compliance mostly useful for.

REFERENCES


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