7ZB-06

Pipeline for the Modeling of Soft Snake Robots Considering Complex Friction Information

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Abstract

Snake-like soft robots are highly adaptable to different kinds of environments with flexibility. A well-studied and feasible locomotion pattern for snake robots is the crawling locomotion with the anisotropic frictional properties of their contact surface. However, due to their frequently changing shapes, the design of the gaits for snake robots is often intuitive and normally derived from either trial and error and simplification of physical structures, making it hard to find an automatically control policy. We propose a modeling pipeline based on a framework for the simulation of soft robots, SoMo [1], which defines the snake body as a concatenation of links connected with joints, allowing users to adjust parameters such as physical properties of joints and frictional properties. This research also lays the foundation of future development of the control system.

1. Introduction

Soft robots are robots with flexible and deformable body. They are highly adaptive, easy to fabricate, and safe to interact with. Many soft robots are bio-inspired such as inching worm-based crawlers, elephant trunk-based manipulators, and snake-like soft robots.

Snake-like soft robots can be used in environmental exploration or disaster recusing missions. One of the special properties of the body of a biological snake is that the snake skin is frictional anisotropy. That is, a biological snake is easier to slide forward but is difficult to slide backward or sideways. This frictional anisotropy enables the undulation locomotion of the snakes. Ta *et al.* in [2] proposed a 3D printable 2D anisotropic frictional skin for a snake-like soft robot. However, the design of the robots requires trial-and-error with physically printed robots that are time consuming. In this paper, we report a pipeline for modeling and simulating the locomotion behaviors of snake-like soft robots with consideration of complex frictional information. Our proposal is built up based on a soft robotic simulation framework - SoMo. It provides a set of pre-defined types of links and joints, as well as methods for planning trajectories and applying torques, enable fast and accurate simulations of soft robots. Our contribution include:

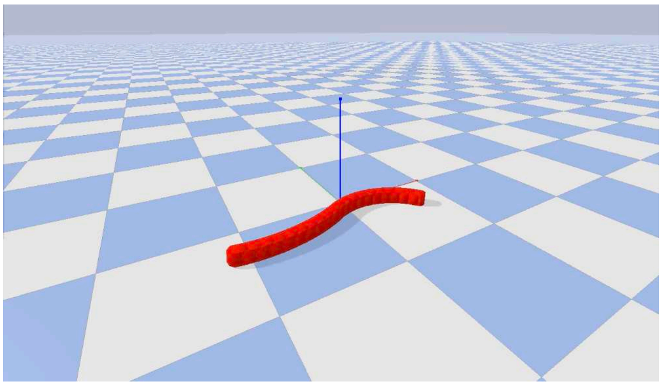

図 1 Simulation of a snake-like soft robot with complex frictional configuration in SoMo with PyBullet [3] as the physics engine.

- Streamlining the modeling and simulation of snake-like soft robots,
- Providing a function to assign frictional property to each body segments of a snake-like soft robot,
- Restructured the codes to facilitate multiple simulation runs and toggle between reading YAML and URDF.
- Evaluating the locomotion performance of a snake-like soft robot with different bodily frictional properties.

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2. Pipeline for Modeling Snake-like Soft Robots with SoMo

One robot generally consists of links and joints connected to each other in a certain order. Links construct the skeleton of the robot. Joints are what connect two neighboring links, allowing them to move relatively to each other. The construction of a robot generally involves designating relative positions, parameters and connecting ways for each link and joint.

Our snake is composed of 2 actuators, each of which are 8 links connected end to end (as shown in Figure 1). The base link of our snake robot is non-shaped and the rest 16 links are "stadium" type with the size of $0.12\ \mathrm{m} \times 0.12\ \mathrm{m} \times 0.05\ \mathrm{m}$. Mass and inertia matrix of each link are 0.595 and the identity matrix. There are two types of joints, able to rotate around x-axis or y-axis. The joints are automatically inserted between links when using YAML format. The parameters such as spring stiffness, effort limitation and angular velocity are available. Here, we have 1300, 100 and 3 separately.

3. Snake-like Soft Robots Experiment

3.1. Environment Setup

This experiment aims at evaluating the locomotion of simulated snake-like soft robots with different configurations of frictional ventral side. We model the snake-like soft robot as a chain of 16 links as mentioned above. Using our developed friction assign function, we are able to set the frictional properties of each link separately. In this experiment, one link can have either high friction (denoted as a bit-1) or low friction (denoted as a bit-0). With this encoding for 16-link chains (*e.g.* "`0000111110000011`"), we have $2^{16} = 65536$ samples for simulating. Our 16-link chain is divided into two body segments which act as two bending actuators. By controlling the bending angle of these two bending actuators, we realize the undulation locomotion of a snake-like soft-bodied robot [2].

3.2. Result

We accessed to the speeds of all the 65536 runs of simulation with different frictional properties each time. The first one-sixteenth of the data is shown in the graph above as Figure 2. The friction configuration is arranged by the binary encodes in ascending order.

Notice that there are spikes appearing, and similar friction configurations do not necessarily mean the similar performance in speed. For example, the highest speed is reached at the configuration of "`000011111000011`", approximately 3 times of average speed. However, many configurations similar to the above will cause the snake nearly not moving, such as "`0000111110000001`" and "`0000111110000000`".

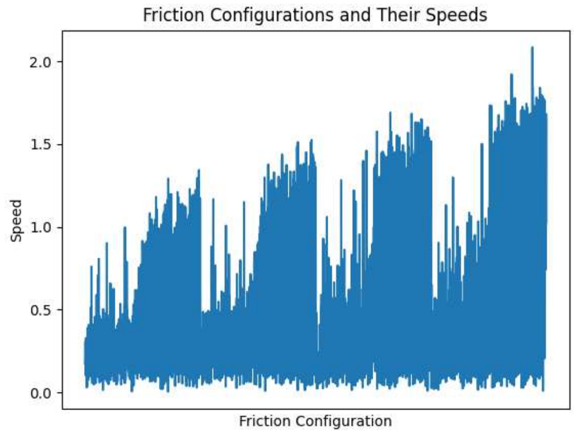

図 2 Simulated locomotion performance of snake-like soft robots with different configurations of friction.

4. Conclusion

In this work, we added features to facilitate the simulation process for snake-like robot considering friction information, and executed a series of simulation runs to find the suitable frictional patterns. The conclusion drown from the data is counter-intuitive. Next, we are planning to build a snake with better mobile ability and design its control system based on the data here.

Reference

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[2] Ta, T. D., Umedachi, T. and Kawahara, Y.: Design of Frictional 2D-Anisotropy Surface for Wriggle Locomotion of Printable Soft-Bodied Robots, *2018 IEEE International Conference on Robotics and Automation (ICRA)*, IEEE, pp. 6779–6785 (2018).

[3] Coumans, E. and Bai, Y.: PyBullet, a Python module for physics simulation for games, robotics and machine learning, `http://pybullet.org` (2016–2021).