Continuous and soft robot modeling based on Cosserat rod theory

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Abstract

Robotics is today experiencing a paradigmatic revolution. The "stiffer is better" of our rigid robots is challenged by a new generation of robots with controlled deformations of finite amplitudes. This is the case of silicon-made soft robots, continuum robots in medical robotics or hyper-redundant eel/snake-robots in bio-inspired robotics. While rigid robotics has been establishing its models and methods since the 80s, this new robotics has long suffered from a lack of a generic modeling framework adapted to its problems. In the case of slender structures, this problem is now being solved thanks to a nonlinear theory of rods now known as Cosserat rod theory.

At the crossroad of rigid body mechanics and continuum mechanics, the Cosserat rod model is an ideal tool for the study of slender bodies undergoing large deformations. Initially presented as an abstract object by the Cosserat brothers, it has been applied over time to many problems in engineering sciences such as structural mechanics, where it gave birth to the geometrically exact finite element method (GE-FEM), in ocean engineering for the simulation of submarine cables, or in computer graphics, for the needs of interactive simulation. In robotics, whether for the study of hyper-redundant bioinspired locomotion, the simulation and control of non-invasive continuous medical robots, or for the design of new concepts of soft arms, it is gradually becoming a standard, comparable to the multi-body models of rigid robotics in the 80's.

In this talk, we will present a modeling framework based on Cosserat rod theory, developed in recent years with the aim of modeling, simulating, analyzing and controlling continuous and soft robots. The approach is based on a new parameterization of the configuration space of Cosserat rods, called "strain-based parameterization". Specifically adapted to the needs and uses of roboticists, we will show how it can be applied to many recently proposed robotic designs.

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