ID de Contribution: **8** Type: **Exposé scientifique**

Differentiable Simulation of Soft Robots with Frictional Contacts

mercredi 18 juin 2025 11:00 (30 minutes)

In recent years, soft robotics simulators have evolved to offer various functionalities, including the simulation of different material types (e.g., elastic, hyper-elastic) and actuation methods (e.g., pneumatic, cable-driven, servo-motor). These simulators also provide tools for various tasks, such as calibration, design, and control. However, efficiently and accurately computing derivatives within these simulators remains a challenge, particularly in the presence of physical contact interactions.
Incorporating these derivatives can, for instance, significantly improve the convergence speed of control methods like reinforcement learning and trajectory optimization, enable gradient-based techniques for design, or facilitate end-to-end machine-learning approaches for model reduction.
This presentation addresses these challenges by introducing a unified method for computing the derivatives of mechanical equations within the finite element method framework, including contact interactions modeled as a nonlinear complementarity problem.
The proposed approach handles both collision and friction phases, accounts for their nonsmooth dynamics, and leverages the sparsity introduced by mesh-based models. Its effectiveness is demonstrated through several examples of controlling and calibrating soft systems.

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Classification de Session: Session 2