Projection-based model order reduction for real-time control of soft robots

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ABSTRACT

Soft Robotics is a new field of robotics that deals with robots whose movements rely on the deformation of soft materials, such as silicone, rather than articulated rigid bodies in "traditional" robotics. Their design is often bio-inspired. Though having a great potential (for example in surgical applications, exploration of cavities, manipulation of fragile objects, etc…), one great challenge lies in their control since they are fundamentally equipped with a theoretically infinite number of degrees of freedom. Some works already proposed their control using a real-time finite element method [1]. The approach was limited by the real-time constraint which forced the use of relatively coarse meshes. This was good enough for a simple application with a unique effector. However, when considering complex geometries, more actuators and several effectors, finer meshes may be necessary, which would not be tractable in real-time.

In this contribution, we attempt to perform real-time realistic simulation of the deformations of the soft robotics structures to achieve the real-time constraint with a converged mesh, meaning fine enough so that further refinement does not modify the result of the simulation. To this purpose, we use the snapshot - proper orthogonal decomposition (snapshot-POD), associated with an energy-conserving sampling and weighting (ECSW) method [2] to keep computational efficiency by only computing mechanical properties on a small subset of the finite elements. The parameter space explored in the offline stage is dictated by the range of the actuators of the soft-robot considered, as well as the possible contacts the robot may encounter. We show that we are able to achieve the real-time constraint with fine meshes.

In further developments, if many actuators are involved, a specific sampling method based on Bayesian optimisation may be used to create the snapshot [3]. The main difficulty will lie on the fact that when the robot enters in contact with its environment, it may endure local deformations not captured by the reduced space. In this case, a partitioning strategy may be necessary [4], to allow for the computation of the local deformations with a full FEM model.

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