FEM model based control design approaches

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Due to their nature and their number of degree of freedom, designing a good controller for soft robotics is a great challenge and has attracted a lot of attention. The literature proposes numerous methods but most of them lack of generality as they are often based on machine learning or are based on shape specific models (for example beams and slender robots). The aim of our work is to propose a set of tools based on Finite Element Method (FEM) model based to create generic approach. FEM is, to us, a good way to describe various deformable shapes and their interaction with their environment. To reach this goal, we have contributed to the numerical framework Sofa (open-source) that can build numerical models based on Finite Element Method (FEM) and simulate them efficiently and interactively. From theses numerical models, we propose various approaches to control soft robots: open or closed loop based on the inverse of the Jacobian matrix (also called quasi-static model inversion), model order reduction based linear state space model approach or the reduced interpolated LPV (Linear Parameter Varying) model based approach. All these controllers are tuned using Lyapunov theory through a set of Linear Matrix Inequalities that are solved using semi-definite programming. They provide both performance and robustness guaranties. All the results are implemented on various robots to show their effectiveness.