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P4.151 A simulation framework for dynamic analysis of flexible robotic mechanisms in DEMO remote maintenance

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The numerical analysis of robotic mechanisms for remote maintenance and inspection inside nuclear fusion reactors has to face several issues. Indeed, these robots are subject to large deformations, which are either induced by their own mechanical structure or by the heavy payloads which they usually handle. In many applications, robotic systems are usually modeled with rigid elements, although different formulations have been developed over the years to handle link and joint flexibility. In order to limit the mathematical complexity, and thus the computational time required for solving the equations of motion, these techniques usually assume linear elasticity and small deflections. In nuclear fusion environments, in particular for the future DEMO reactor, the large loads induce nonlinear behaviors which need to be predicted with details so as to plan safe and collision-free autonomous remote operations. Therefore, an accurate nonlinear finite element approach based on geometrically exact models is highly desirable.
To simulate robots subject to large deformations, we use a screw-based nonlinear finite element formulation. Finite element procedures have the advantages of: (i) modeling manipulators with rigid and/or flexible arms; (ii) modeling manipulators with rigid and/or flexible joints; (iii) modeling manipulators structured in a serial or parallel topology using the same systematic approach. These features are particularly appealing in the context of robotic autonomous maintenance and inspection in tokamak machines, where high complex mechanisms are involved in usual operations. Furthermore, the screw-based approach yields to a global parametrization-free framework. This allows solving the equations of motion using geometric time integrators, which significantly speed up the computation.
In this work, we present a simulation framework for dynamic analysis of flexible robotic mechanisms used for nuclear fusion applications. We show the potentialities of the approach by simulating: (1) an hybrid serial/parallel flexible robotic mechanism; (2) an hyper-redundant flexible manipulator.

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