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A general modelling and control framework for electrostatically actuated mechanical systems. (English summary)

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Electrostatic actuation of micro-electromechanical systems (MEMS) uses attractive Coulomb forces that develop between capacitively coupled conductors differing in voltage. Electrostatically actuated MEMS are popular because they are simple in structure, flexible in operation, and may be fabricated from standard, well understood, materials. This paper presents a geometric framework for the stabilization and control of a general class of electrostatically actuated mechanical systems. Electrostatic actuation is poised to be the method of choice for the emerging field of nanoelectromechanical systems (NEMS) and the proposed approach should be applicable there as well. The general electrostatic force model is integrated into equations of motion for a simple mechanical system with configuration space described by a Lie group. The Lie group setting is quite general, and can incorporate rigid rotation and translation, flexible bodies, and combinations of these. The class of devices under study consists of a movable, rigid, grounded electrode, with a variety of allowable rotational and/or translation degrees of freedom, and a set of multiple, fixed, independently addressable, drive electrodes. A key contribution of this paper places general electrostatic forces in a framework suitable for passivity-based control. The stabilizing static and dynamic feedback control laws are derived in terms of co-ordinate-independent geometric formulas. To obtain controllers for a specific device it is then necessary only to evaluate these formulas. Appropriate approximations may be applied to make the computations more tractable. The static output feedback controller requires only measurement of the charge and voltage on each drive electrode to provide almost-global stabilization of a desired feasible configuration, but performance is limited by the natural dynamics of the mechanical subsystem. Performance may be improved using dynamic output feedback, but additional information is needed, typically in the form of a model relating electrode capacitances to the system configuration. The geometric formulation is specified for a MEMS device of interest, and the results validated using finite-element ANSYS simulations.

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