Multiphysics-based controlled shape change in soft materials

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Abstract

A precise controlled shape change of responsive materials requires the development of theoretical and computational approaches capable of reproducing the involved physical phenomena and their interaction. When polymer-based materials are considered, shape change capabilities can be obtained from external stimuli, such as temperature, light, humidity, electric field, etc. These stimuli, if precisely spatiotemporally controlled, can deform a structure into a desired configuration in a given time. The paper investigates the multiphysics-based driven shape change in highly deformable composite structures made of a passive elastic structure and an active one capable of responding to environmental stimuli. By harnessing different mechanisms, namely 1) the swelling of gels (1) and 2) the deformation of electro-active dielectric elastomers (DE) (2), controlled mechanical stresses can be transmitted to the passive portion leading to its deformation. In the present study, an elastic tube filled with a gel, whose volume deformation is driven by the fluid uptake (3), and a bilayer structure made of an elastic substrate and a DE active layer, whose deformation is induced by an electric potential (4), are considered as morphing structures. It is shown that by properly distributing the mechanical properties in the hyperelastic passive element interacting with the responsive active material, a precise shape change can be achieved. To this end, we numerically solve the multyphysics coupled problems and adopt a machine learning (ML) approach for solving the inverse problem. Given a prescribed target shape, the proposed approach enables to obtain the proper spatial stiffness distribution of the passive elastic element enabling the achievement of the desired deformed configuration.

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