Elementary Morphing Shells

Evripides G. Loukaides

Abstract

Multistable shells are not yet completely understood. Even under the widespread Uniform Curvature (UC) assumption, the limits of this behaviour have not been established and the influence of individual material and geometric parameters has not been described conclusively; this research explores these open questions. In addition, this project was motivated by the need for practical design guidelines and the pursuit of alternative construction and actuation methods for multistable shells. Our analysis is based on an expression for the strain energy of a shell under a set of simplifying assumptions—primarily the aforementioned UC assumption. We extend this concept beyond the work of previous authors by admitting a more diverse range of anisotropic materials. Furthermore, we take advantage of some aspects of the mathematical field of Catastrophe Theory (CT) to maximise the generality of available results. When appropriate, we examine aspects of our predictions by constructing relevant shell structures, with particular focus on material considerations. A commercial Finite Element Analysis package provides additional means of analysis and comparison. On the theoretical front, the influence of certain control parameters on the availability of multistability is described in closed-form while a unique graphical overview of the limits of this behaviour is provided. In the lab, a novel tristable shell is constructed from a laminate and the use of specialized materials is scrutinised. In a subsequent project, a bistable spherical cap made from a customized material is actuated by a magnetic field—the ensuing snap-through event is recorded with a high-speed camera, leading to valuable insights on the transition geometry. Furthermore, we confirm the possibility of bistability for developable, non-prestressed shells, composed of a single material, using grid shells and thin honeycomb shells.