Control-based continuation: bifurcation and stability analysis for physical experiments

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Abstract

Control-based continuation is technique for tracking the solutions and bifurcations of nonlinear experiments. The basic idea is to apply the method of numerical continuation to a feedback-controlled physical experiment. Since in an experiment it is not (generally) possible to set the state of the system directly, the control target is used as a proxy for the state. The challenge then becomes to determine a control target such that the control is non-invasive, that is, it stabilises a steady-state (or periodic orbit) of the original open-loop experiment without altering it otherwise. Once implemented, control-based continuation enables the systematic investigation of the bifurcation structure of a physical system, much like if it had been a numerical model. However, stability information (and hence bifurcation detection and classification) is not readily available due to the presence of feedback control. This paper uses methods from the system identification community to extract stability information in the form of Floquet multipliers from the closed-loop experiment, thus enabling the direct detection of bifurcations. In particular, it is shown that a periodic auto-regressive moving-average model with exogenous inputs (ARMAX) can be constructed that approximates the time-varying linearisation of the experiment around a particular periodic orbit. This method is demonstrated using a physical nonlinear tuned mass damper.

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