Dynamics and multistability of Church Bells

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When designing or monitoring the supporting structures of church bells, the dynamics of their swing is a crucial factor to consider. The response of the yoke-bell-clapper system is determined by the geometry of the yoke and the magnitude of the excitation force because the size and shape of the bell usually cannot be changed. This work introduces a yoke-bell-clapper system. A mathematical model, based on an existing prototype, is presented [1]. Then experimental switching between two attractors in a swinging bell system is shown. In the examined yoke–bell–clapper configuration, two coexisting solutions are observed: one where a single impact occurs between the bell and the clapper per one period of motion, producing sound, and another where no impacts occur, resulting in silence. By employing the time-dependent stability margin method, we numerically identify trajectory segments where the system is most susceptible to perturbations. Utilizing this information, we experimentally induce switching between attractors by applying perturbations to the clapper. We show that timing the perturbation correctly allows us to easily enforce the change of solution [2]. Our results confirm that, based on insights from the time-dependent stability margin method, we can effectively correct the bell's operation from the no-impact state to the impact state. The research successfully employs novel methods for investigating multistable systems and highlights the complex phenomenon of multistability in the dynamical system.

References

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