A novel iterative procedure for dynamic integrity assessment

Giuseppe Habib
Dept. of Applied Mechanics, Budapest University of Technology and Economics, Budapest, Hungary
E-mail: habib@mm.bme.hu

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Local stability is one of the most critical properties of a dynamical state. Engineers heavily exploit this concept. Nevertheless, scientists dealing with dynamical systems are aware that, despite its local stability, a system might diverge from its state if subject to a perturbation sufficient to make it cross the boundary of its basin of attraction (BOA). However, calculating a system's BOAs is computationally demanding and rarely done in practice.

The objective of this study is to develop an algorithm for the robustness assessment of equilibrium points. The procedure reduces the computational cost for global stability analysis by identifying the so-called local integrity measure (LIM) [1] only, overlooking fractal and intermingled portions of the BOA, which are hard to identify and practically less relevant. The algorithm is based on a simple iterative framework. An initial trajectory of the system in the phase space is computed. If the trajectory does not converge to the desired solution, the LIM is estimated as the minimal distance between the equilibrium point of interest and any point of the non-convergent trajectory. The new estimated value of the LIM defines a hypersphere in the phase space, which limits the region of interest. The procedure is then repeated iteratively. A cell subdivision of the phase space is exploited to automatically classify the trajectories and reduce computational time.

The algorithm was implemented on systems of various dimensions, which illustrated that it can rapidly and efficiently estimate the LIM value in all cases studied. In particular, the first few iterations already provided a relatively accurate estimate of the real LIM value. An illustrative case is shown in Fig. 1 for a Duffing-van der Pol oscillator, with an attached tuned mass damper. The obtained results suggest that the proposed algorithm is a viable option for the robustness assessment of dynamical states.

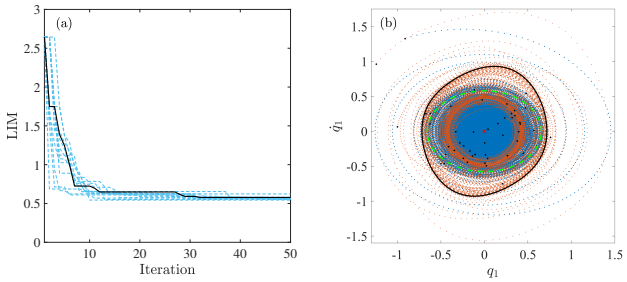

Fig. 1: (a) LIM estimated value; (b) projection of the points tracked during the computation; blue and red points: converging and non-converging points, respectively, dashed green line: section of the hypersphere of convergence.

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References

[1] *Lenci, S. and Rega, G., Global Nonlinear Dynamics for Engineering Design and System Safety. Springer, Berlin (2019).*