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Restoring chaos using deep reinforcement learning

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A catastrophic bifurcation in non-linear dynamical systems, called crisis, often leads to their convergence to an undesirable non-chaotic state after some initial chaotic transients. Preventing such behavior has been quite challenging. We demonstrate that deep Reinforcement Learning (RL) is able to restore chaos in a transiently chaotic regime of the Lorenz system of equations. Without requiring any a priori knowledge of the underlying dynamics of the governing equations, the RL agent discovers an effective strategy for perturbing the parameters of the Lorenz system such that the chaotic trajectory is sustained. We analyze the agent's autonomous control-decisions and identify and implement a simple control-law that successfully restores chaos in the Lorenz system. Our results demonstrate the utility of using deep RL for controlling the occurrence of catastrophes in non-linear dynamical systems.

Numerous examples arise in fields ranging from mechanics to biology where the disappearance of chaos can be detrimental. Preventing such transient nature of chaos has proved to be quite challenging. In this paper, we demonstrate that Reinforcement Learning (RL), which is a specific class of machine-learning techniques, is capable of discovering effective control mechanisms in this regard. The autonomous control algorithm is able to prevent the disappearance of chaos in a specific non-linear system, without requiring any a priori knowledge about the underlying dynamics. We analyze the autonomous decisions taken by the algorithm to understand how the system's dynamics are impacted, which in turn allows us to formulate a simple control-law capable of restoring chaotic behavior. The reverse-engineering approach adopted underlines the immense potential of the techniques used here to discover effective control strategies in complex dynamical systems. We note that the autonomous nature of the learning algorithm makes it applicable to a diverse variety of non-linear systems, which highlights the potential of RL-enabled control for regulating other crisis-like catastrophic events.
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