An Explicit Slow Manifold-Based Model Reduction Method for Nonlinear Discrete-Time Dynamical Systems

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The present research work proposes a new approach to the model-reduction problem for nonlinear dynamical systems in the discrete-time domain based on the notion of slow manifold. The formulation of the problem is realized through a system of nonlinear first-order functional equations (NFEs) that represent map invariance equations associated with the nonlinear discrete dynamics under consideration. In particular, within the class of analytic solutions a set of conditions is derived that guarantees the existence and uniqueness of a locally analytic solution. The solution of the aforementioned system of invariance NFEs is proven to be an explicit mathematical characterization of a locally analytic slow invariant manifold, and the local analyticity property of the manifold enables the development of a series solution method which can be easily implemented with the aid of a symbolic software package such as MAPLE. Under a certain set of conditions, it is shown that the above slow manifold attracts all system trajectories, and therefore, model reduction is realized through the restriction of the discrete-time system dynamics on the slow manifold. Finally, the proposed approach is illustrated and evaluated in a representative biological reactor example.