

# APPLICATION OF SWARM INTELLIGENCE TO BIFURCATION ANALYSIS

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## ● Background

### ◇ DYNAMICAL SYSTEMS

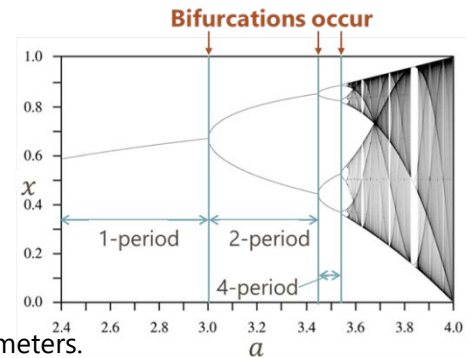
- ◇ Complex real-world dynamics can be modeled as dynamical systems.
- ◇ Analyzing dynamical systems is important to solve a variety of problems in the real world.

### ◇ BIFURCATION

- ◇ Dynamical systems mostly contain one or more parameters.
- ◇ Bifurcation occurs when a small change, applied to the parameter values of a system, causes a sudden qualitative change in the periodic solutions' behavior.
- ◇ Bifurcation analysis, which investigates how bifurcation depend on the system parameters, is one of the most important nonlinear analysis techniques for understanding phenomena of systems.

### ◇ BIFURCATION PARAMETER DETECTION METHODS

- ◇ Brute-force method requires larger amount of calculations.
- ◇ The classic methods based on Newton method require the derivative of the objective functions and appropriate initial conditions.



## ● Proposal of Bifurcation Parameter Detection Strategy Based on Particle Swarm Optimization

### ◇ PARTICLE SWARM OPTIMIZATION (PSO)

- ◇ is one of the simplest population-based optimization techniques.
- ◇ avoids the derivative of the objective function.

### ◇ BIFURCATION PARAMETER DETECTION STRATEGY BY USING THE NESTED-LAYER PSO (NLPSO)

- ◇ is a **non-Newton method** and is performed by two nested PSOs.
- ◇ requires **no strict settings of initial values** or **cumbersome manual calculations**.
- ◇ can accurately and directly find the bifurcation parameters set.
- ◇ can obtain a bifurcation diagram of **both unstable and stable periodic points**.
- ◇ is applicable to detection of
  - ◇ local bifurcations including **period-doubling, saddle-node and Neimark-Sacker bifurcations**.
  - ◇ **border-collision bifurcations** in piecewise smooth maps.

