

A Novel Clustering-based Approach for Analyzing Behavior in Nonlinear Dynamical Systems Using Self-Organizing Maps

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1: RESEARCH QUESTION



Varying parameters—
different dynamics,
or similar behavior under
fixed initial conditions?

2: MOTIVATION

- In nonlinear dynamical systems, behavior is typically studied by **fixing parameters** and **varying initial conditions**, often leading to chaotic and unpredictable outcomes.
- This work instead **fixes initial conditions** and **varies system parameters** to explore how system behavior evolves.
- Parameter variation produces **a large number of trajectories**, making interpretation difficult using conventional methods.
- **Clustering** organizes trajectories into groups, revealing similar behaviors, distinct patterns, and transition regions.

3: DYNAMICAL SYSTEM

Case Study: Selkov Glycolysis Model

$$\frac{dx}{dt} = -x + ay + x^2 y,$$

$$\frac{dy}{dt} = b - ay - x^2 y,$$

$x(t)$: ADP Concentration
 $y(t)$: F6P Concentration

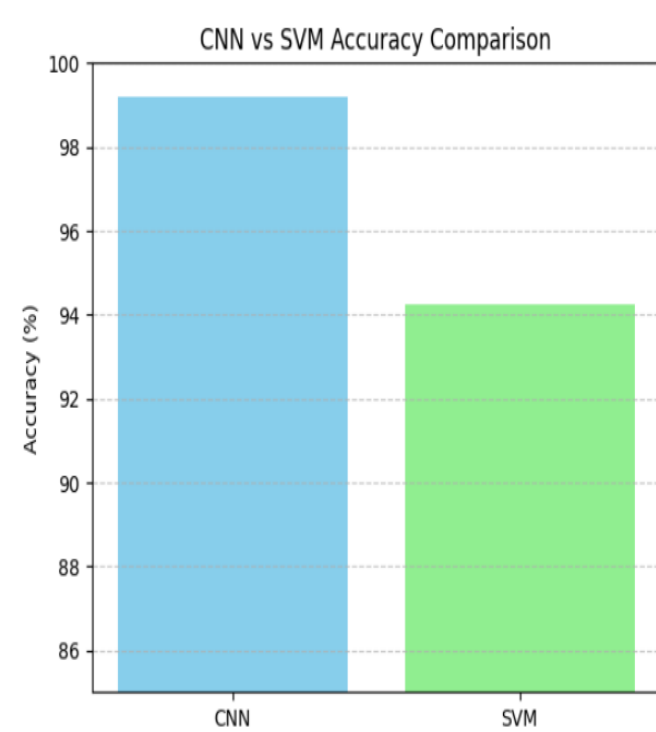
Parameters: $a, b > 0$

Initial conditions: $x(0) = 1, y(0) = 0$.

The **Selkov model** is a nonlinear dynamical system whose behavior depends on system parameters. It enables the generation of diverse trajectories, helping to identify similar patterns, distinct behaviors, and transition regions.

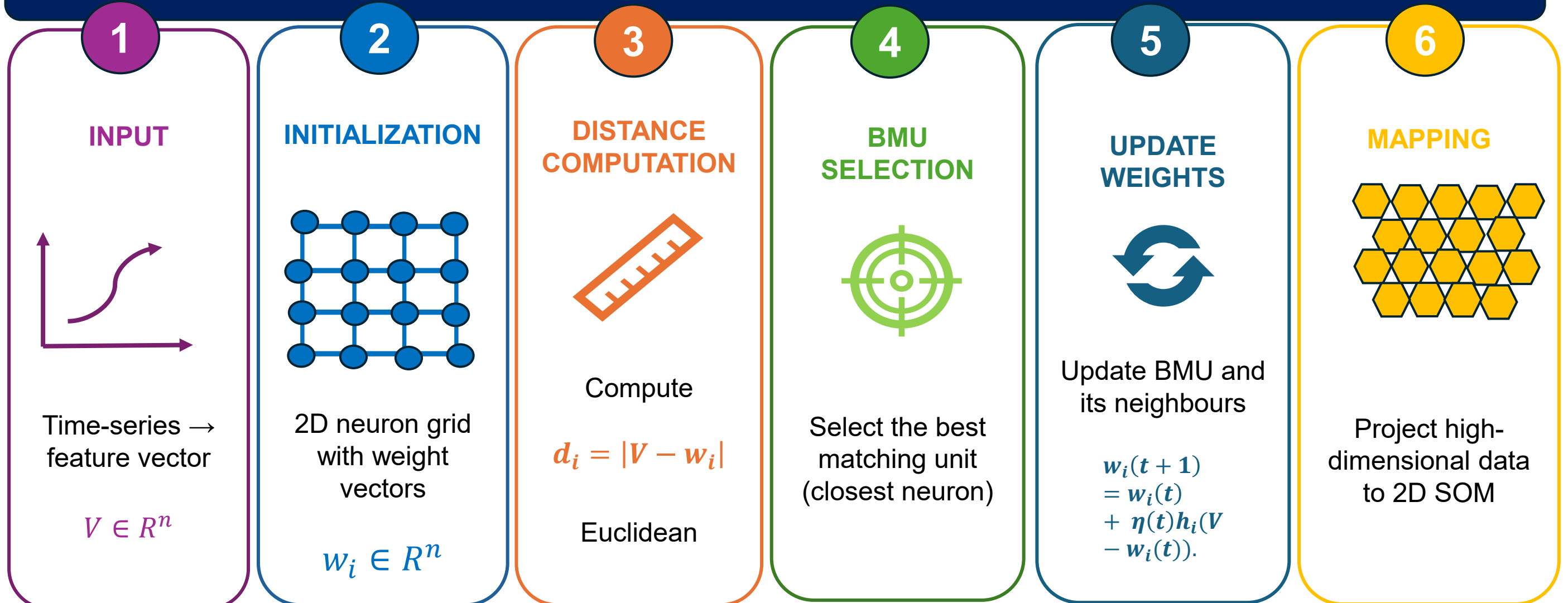
7: VALIDATION AND PERFORMANCE COMPARISON

- ❖ A comparative evaluation was conducted to assess the classification accuracy of **CNN** and **SVM**.
- ❖ CNN achieves higher accuracy than SVM, indicating better classification performance.
- ❖ This improvement is due to CNN's ability to learn complex patterns, while SVM relies on predefined features.



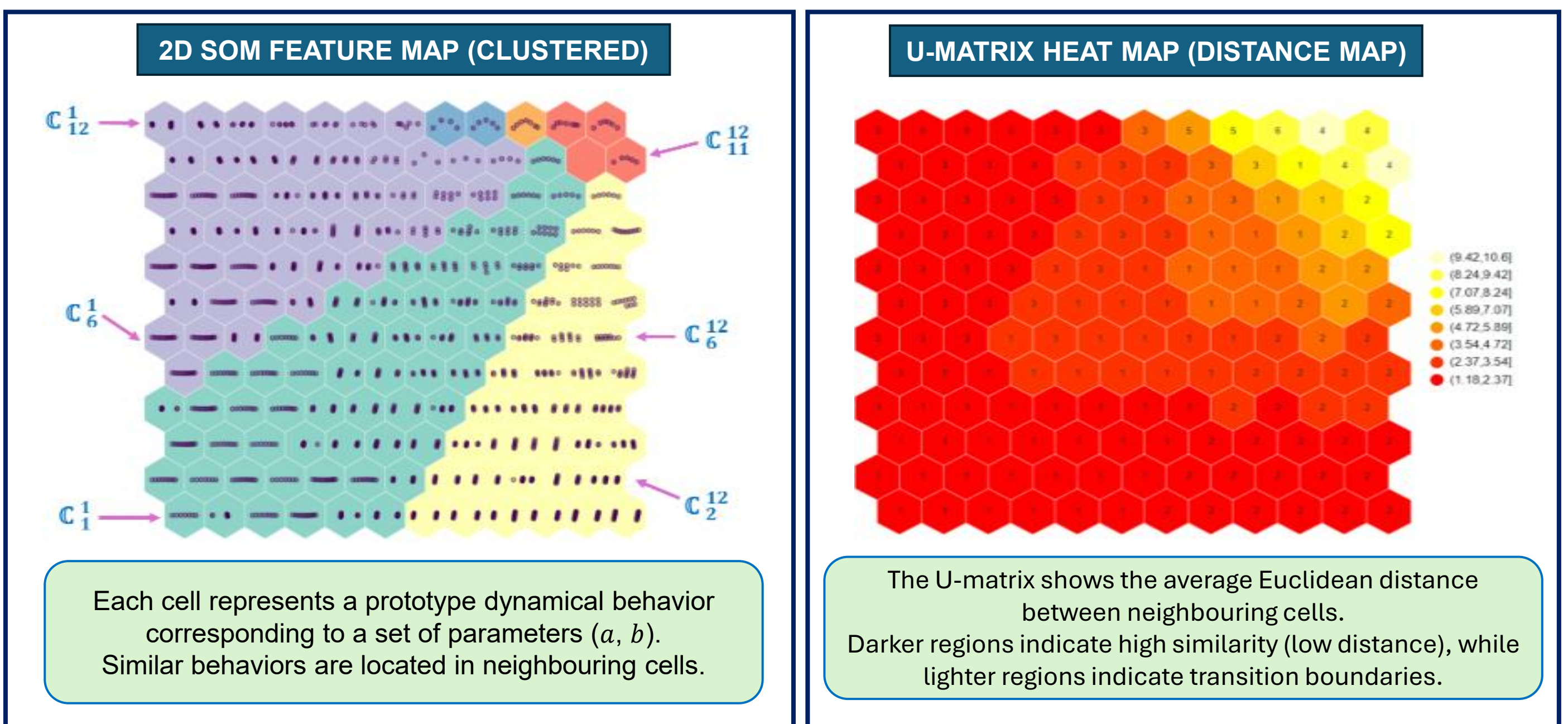
Comparison of CNN and SVM accuracy based on similarity index.

4: METHODOLOGY



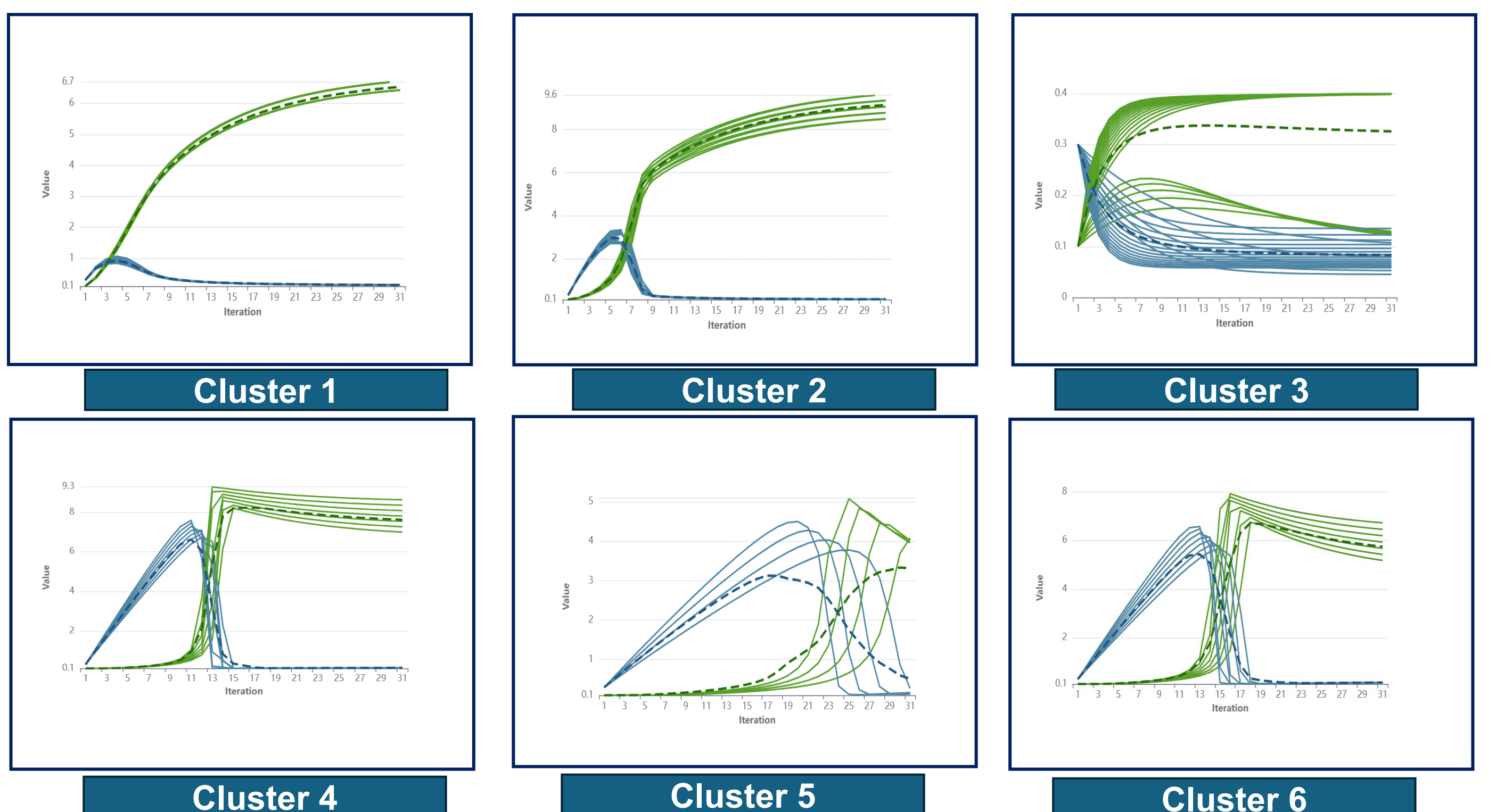
5: SOM REPRESENTATION & CLUSTER STRUCTURE

Mapping Dynamics into Structured Behavioral Patterns



6: RESULTS

Representative Dynamical Patterns of the Six Identified Clusters



8: Conclusion

By fixing initial conditions and varying system parameters, the study shows that system behavior is not random but follows consistent patterns. Despite generating many trajectories, similar behaviors emerge, revealing underlying structure. Clustering effectively groups these patterns and identifies transitions, while validation (~99% accuracy) confirms their reliability.

