



Pattern Discovery and Networks

Cosma R. Shalizi

Dynamics of Learning Group, Santa Fe Institute

Infospherics Meeting, 18 July 2001

■ Pattern Discovery:

Analysis of “pattern”, “organization”, dynamics of learning

Computational mechanics: a method for building optimal causal models from data

New results on the limitations of statistical learning systems

■ Applications to Networks:

Infer network structure from data

Measures of collective function

Relate collective performance to network structure

■ Goals:

Theory: basic constraints, quantitative predictions

Implementation: New algorithms, data-sets

Computational Mechanics: Mathematical Foundations

- Basic setting: predicting stochastic processes
- Causal state = Condition of knowledge about future
- ϵ -Machines = {Causal states, Transitions}
- Optimality Theorem:
 - ϵ -Machines are optimal predictors
- Minimality Theorem:
 - Of the optimal predictors, ϵ -machines are smallest/simplest
- Uniqueness Theorem:
 - Up to isomorphism, the ϵ -machine is unique
- The Point:
 - Discovering an ϵ -machine is the goal for any learning

Computational Mechanics: Applications

■ Time Series

Hidden Markov models

Intrinsic computation in dynamics

Experimental data

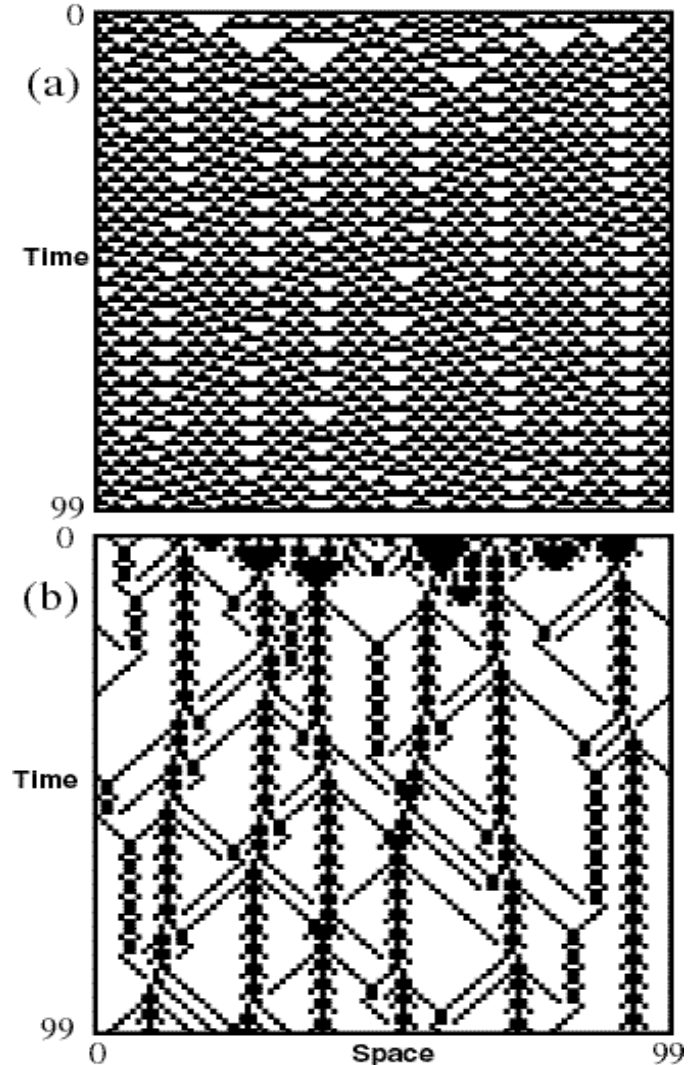
Turbulent flows, climate modeling

■ Spatiotemporal Systems

Cellular automata

Detection of emergent structures

Evolution of emergent
computation



Computational Mechanics for Networks

■ ε -Machine Nets

Each node in network gets its own machine; interactions

Machines represent intrinsic computation of each node

ε -Machine net represents intrinsic global computation

■ Collective Properties

Measure complexity/memory of network vs. components

Measure collective function

■ Inference

Network links = causal connections

Infer network structure as well as architecture of nodes

■ Collective Cognition