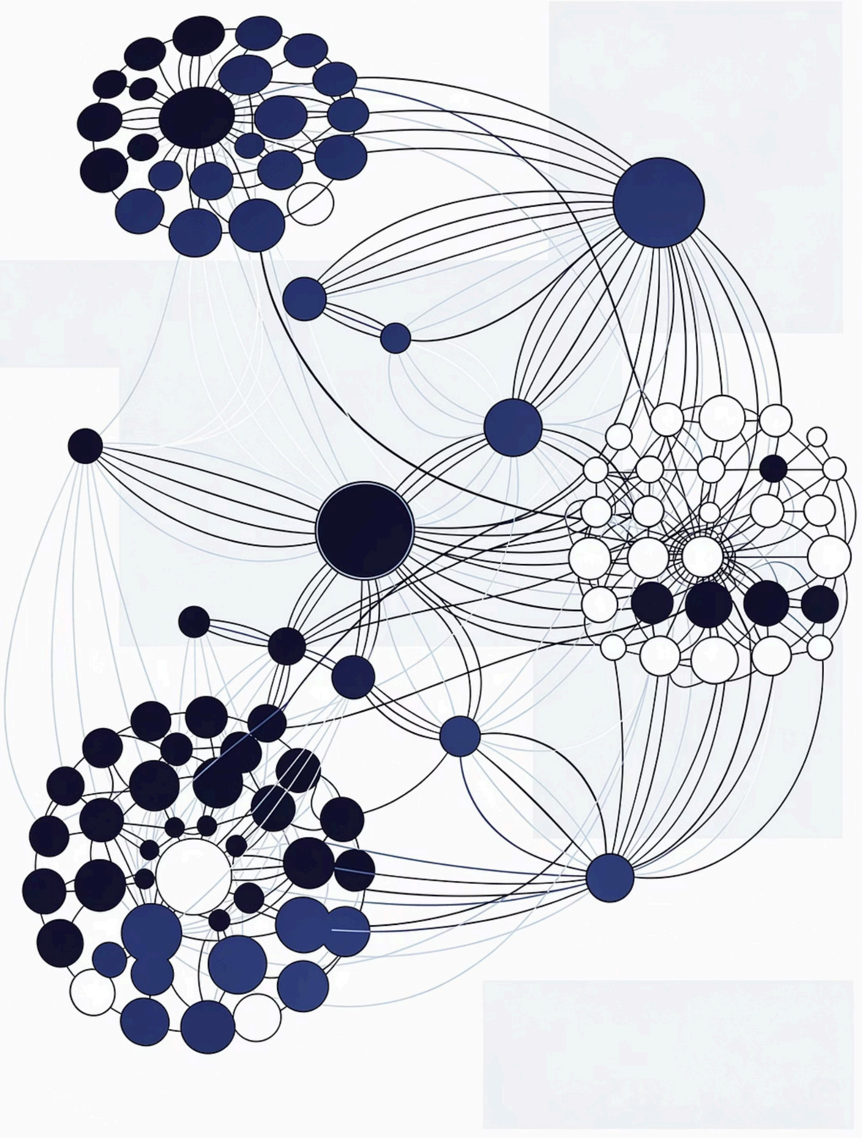
# Advanced Computational Techniques for Modeling Social Phenomena

A comprehensive exploration of computational methods for modeling and optimizing complex social systems, integrating optimization techniques, evolutionary algorithms, and game theory with practical Python implementations.



COURSE OVERVIEW

# Course Structure and Learning Journey

This interdisciplinary course combines theoretical foundations from complexity economics with practical computational implementations. Through 12 lecture sessions, students explore advanced methods for analyzing social systems from computational and evolutionary perspectives.

The curriculum progresses from optimization fundamentals through evolutionary algorithms to sophisticated applications in complex social system modeling, culminating in integrated assessment frameworks.

### Key Learning Outcomes

- Formulate optimization problems for social phenomena
- Implement evolutionary algorithms
- Model complex social systems
- Apply evolutionary game theory

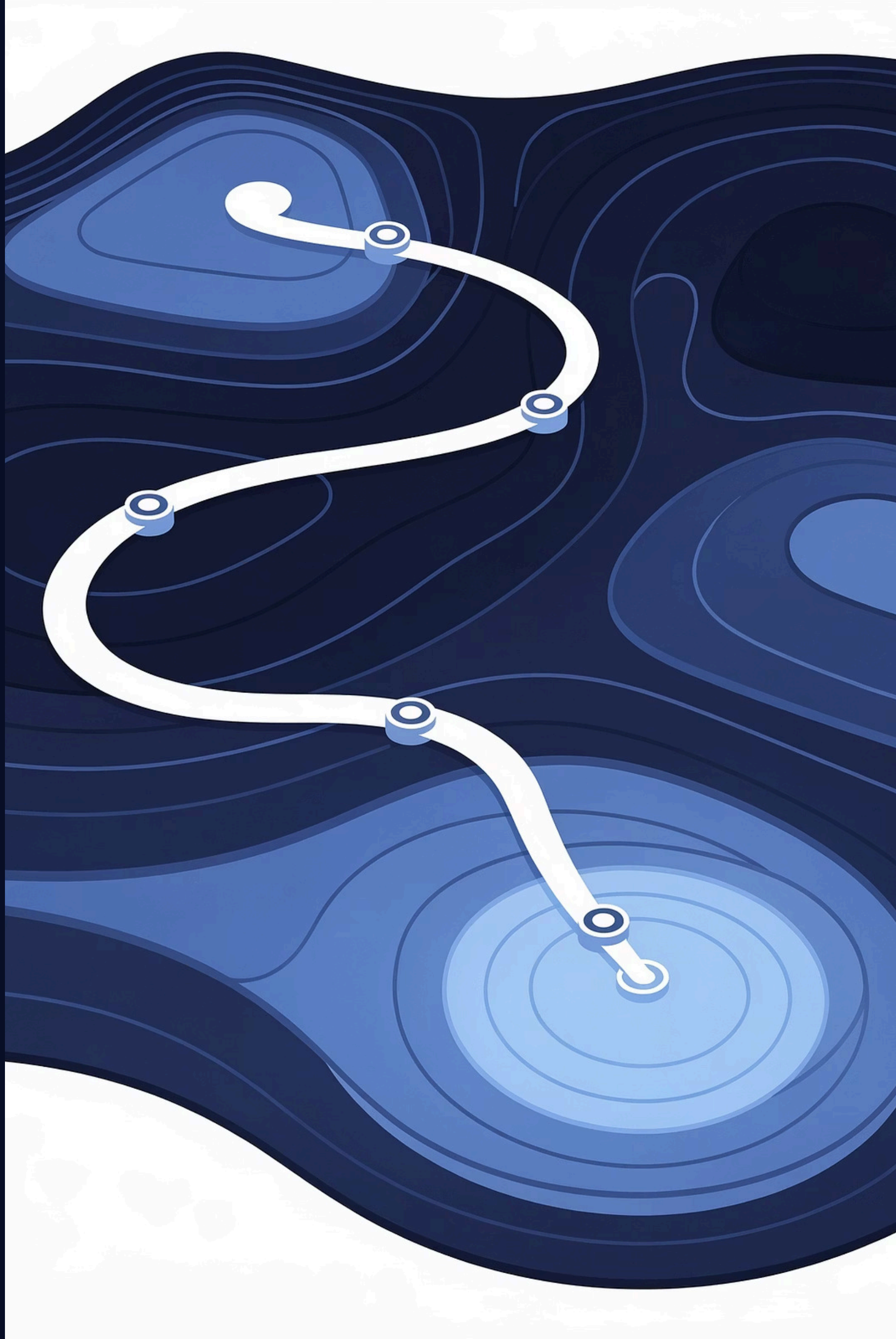
# Foundations: Optimization and Gradient Descent

### Optimization Fundamentals

Mathematical formulation of maximization and minimization problems, constraints, feasible regions, and the distinction between local and global solutions.

### Gradient Descent Algorithm

Implementation of gradient-based optimization using derivatives in multiple dimensions, enabling efficient navigation of complex solution spaces.



# Complexity Economics and Stochastic Methods

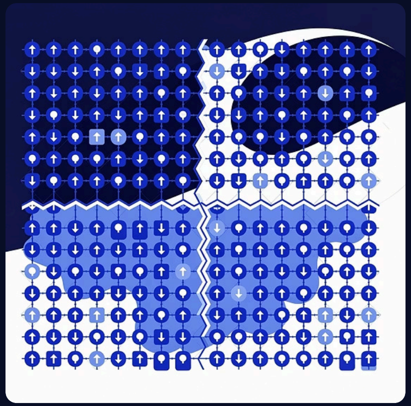
## Session 1: Complexity Economics

Theoretical foundations of complex adaptive systems and their application to economic and social analysis, establishing the framework for understanding emergent phenomena in social systems.

## Session 1.a: Monte Carlo and Markov Chains

Stochastic simulation methods including Monte Carlo techniques for modeling uncertainty and Markov chains for analyzing sequential social phenomena with practical implementation strategies.

# Social Physics: Ising and Schelling Models

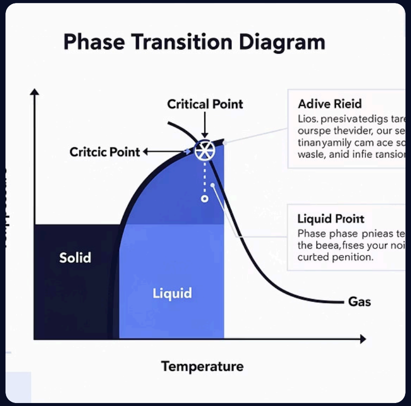


## Ising Model Applications

Statistical physics framework applied to social sciences, modeling collective behavior and opinion dynamics through spin interactions and phase transitions.

## Schelling Segregation Model

Residential segregation dynamics and social clustering, demonstrating how individual preferences lead to emergent macro-level patterns in urban environments.




## Phase Transitions

Critical phenomena in social systems where small parameter changes trigger dramatic collective behavioral shifts, analogous to physical phase transitions.

# Information Theory: Entropy in Social Systems

## Entropy Concepts

Measuring disorder, information content, and complexity in social phenomena through entropy-based metrics.

01

### Information Entropy

Quantifying uncertainty and information content in social data distributions

02

### Social System Entropy

Applying entropy measures to analyze social organization and disorder

03

### Complexity Measurement

Using entropy-based metrics to assess system complexity and predictability

# Evolutionary Algorithms: Genetic Algorithms

### Encoding

Binary and real-valued representation of solutions as chromosomes

### Selection

Fitness-based selection mechanisms for parent chromosomes

### Reproduction

Crossover and mutation operators creating new generations

Genetic algorithms mimic natural evolution to solve complex optimization problems, using population-based search with selection pressure driving convergence toward optimal solutions.

# Advanced Optimization Techniques

### Particle Swarm Optimization

Swarm intelligence algorithm where particles explore solution space through social learning, balancing individual experience with collective knowledge for multi-agent system optimization.

### Differential Evolution

Population-based optimization using mutation and recombination strategies for continuous optimization, offering advantages in handling multi-modal landscapes.

### Fitness Function Design

Formulating objective functions that capture problem constraints and goals, critical for guiding evolutionary search toward meaningful solutions.

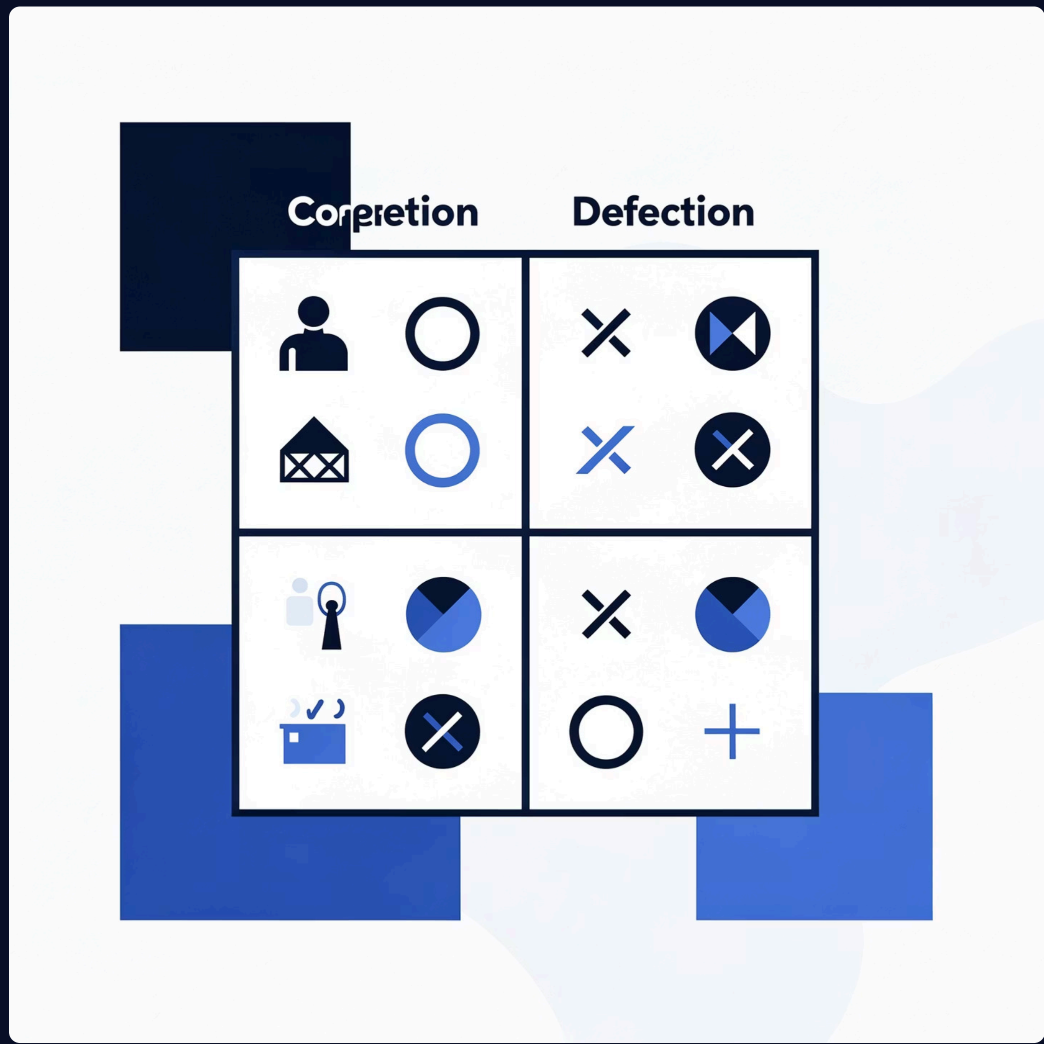
# Game Theory and Evolutionary Cooperation

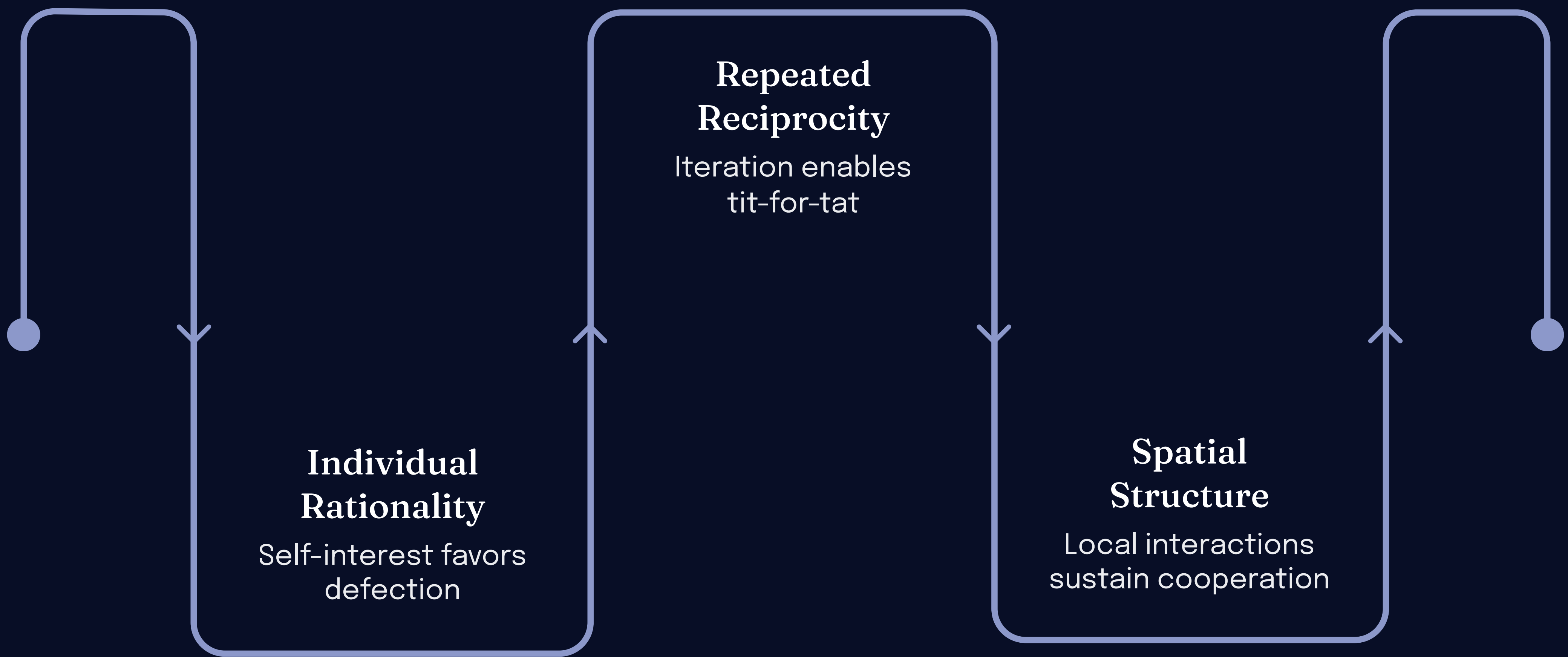
## Classical Game Theory

Analysis of strategic interactions including the Prisoner's Dilemma, Hawk-Dove games, and Nash equilibria. These frameworks reveal how rational agents make decisions in competitive and cooperative scenarios.

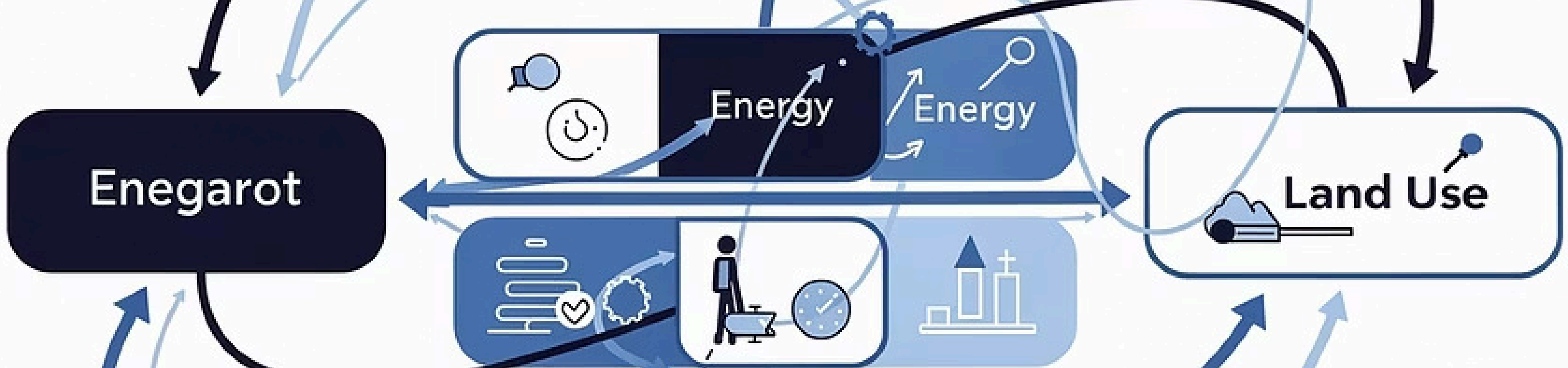
## Evolutionary Game Theory

Replicator dynamics and evolutionary stable strategies explain how cooperation emerges in populations through repeated interactions and spatial structure, even when individual rationality suggests defection.




The iterated prisoner's dilemma demonstrates how evolutionary strategies like tit-for-tat can outperform purely selfish approaches, providing insights into the emergence of cooperative behavior in social systems.




ADVANCED APPLICATIONS

# Integrated Assessment: EDIAM Framework

The Exploratory-Dynamic Integrated Assessment Model (EDIAM) represents the culmination of computational techniques for analyzing complex social phenomena. This framework combines optimization algorithms, evolutionary methods, and dynamic modeling to evaluate policies and interventions in multi-dimensional social systems.

### Model Integration

Combining multiple modeling approaches into unified framework

### Exploratory Analysis

Testing scenarios and uncertainty in complex systems

1

2

3

### Dynamic Evaluation

Assessing policy impacts across temporal dimensions

> EDIAM enables comprehensive analysis of social phenomena by integrating computational optimization, evolutionary algorithms, and dynamic assessment methodologies into a cohesive analytical framework for policy evaluation and decision support.