

Viva topics CO923

Introduction to Complexity

- Characteristics of complex systems. Examples.
- What are models for?

Cellular Automata and Conway's Game of Life

- Definition of cellular automaton.
- Wolfram's classes of patterns.
- Conway's Game of Life.

Statistical Physics and Monte Carlo methods

- Microstates, macrostates.
- Ensembles, partition function, expectations.
- Transition rates, ergodicity.
- Postulates, universality.
- Relation between statistical physics and complexity.
- Markov chain, Monte Carlo methods, Metropolis algorithm.

Criticality and the Ising model

- Phase transitions, criticality.
- Ising model – definition, order parameter, mean field solution.
- Metropolis algorithm applied to the Ising model.

Neuroscience and the Hopfield model

- Describe neurons, action potentials, neural networks.
- Pavlov, Hebb rule.
- Amari-Hopfield model – simulation, associative memory, applications.

Self-organised criticality

- Fractals, self-similarity, fractal dimension.
- Scale invariance, power laws, pink noise.
- Characteristics of self-organised criticality.
- SOC models: sand pile, forest fire, punctuated equilibrium.

Introduction to complex networks

- Degree distribution, paths, connectivity.
- Erdős-Rényi random graphs.
- Small worlds, Watts-Strogatz model.
- Scale-free networks, Barabási-Albert model.
- Dynamics on complex networks.

Neural network dynamics

- Effects of network topology.
- Computation at the edge of chaos.
- Models of short-term memory.

Sociophysics

- Voter model.
- Axelrod's model of dissemination of culture.
- Is sociophysics useful?

Cooperation

- Definition and examples of cooperation.
- Game theory, Nash equilibrium.
- Prisoner's Dilemma, and Iterated Prisoner's Dilemma.
- Axelrod's tournament and conditions for success.
- Evolutionary game theory, evolutionarily stable strategy, examples.
- Routes to altruism: kin selection/inclusive fitness, direct reciprocity, indirect reciprocity.

Evolution and genetic algorithms

- Evolution of evolutionary thinking.
- Examples of evolution.
- Fitness landscape.
- Types of selection: sexual selection, kin selection, r/K selection, other types.
- Genetic algorithms: implementation, example problems.

Stochastic optimization

- What is stochastic optimization and why is it used?
- Simulated annealing.
- Ant colony optimization.
- Implementation, example problems.