Computer simulations in physics: Exam questions

May 25, 2022

1. Random numbers

    (a) What is the difference between true and pseudo random numbers

    (b) Define the Multiplicative congruential algorithm

    (c) What is the Marsaglia effect

    (d) Define the method to obtain arbitrary random number distributions

    (e) What is the Box-Müller method?

    (f) Define the Monte Carlo integration

2. Molecular dynamics

    (a) Define the distance calculation using periodic condition both for square and sheared boxes

    (b) Define the main steps of the molecular dynamics

    (c) What is the problem with frictional forces and describe the solution

    (d) Describe the cell list algorithm

    (e) What is the Ewald summation

    (f) Which integrators are time reversible, why is it important?

    (g) Describe the Nosé-Hoover thermostat

3. Discrete element methods

    (a) Define the Event driven algorithm

    (b) What is the inelastic collapse

    (c) Describe the Contact dynamics and how the forces are calculated (do not need formula)

(d) Define the Kinetic Monte Carlo algorithm

(e) Describe the three different methods of parallelization, with some of their advantages and disadvantages

4. Percolation, Fractals

   (a) Define the percolation model

   (b) Define the order parameter, the mean cluster size distributuion and their behavior around the critical point

   (c) Define the Hoshen-Kopelman algorithm

   (d) Define the fractals

   (e) What is the fractal dimension and how can be measured

   (f) Define the Diffusion Limited Aggregation

   (g) Define the Kadar-Parisi-Zhang equation

5. Ising model

   (a) What is importance sampling

   (b) Define the Metropolis algorithm

   (c) What is a cluster algorithm, how do they work?

   (d) How can one simulate Microcanonical ensemble?

   (e) How can one calculate the Free energy in an Ising system?

   (f) Define the Finite size scaling

   (g) Define the Schelling model

6. Optimization

   (a) Define steepest descent algorithm and the conjugate Gradient Method

   (b) What is a rugged energy landscape?

   (c) Linear regression: definition

   (d) Simulated annealing: definition

   (e) Genetic algorithm: algorithm

7. Complex networks

   (a) Define a general network (graph) and the adjacency matrix

   (b) What is the difference between a Poissonian and a scale free network?

    (c) Define the Dijkstra algorithm

    (d) What is the small world property?

    (e) Define the clustering coefficient

    (f) Define the Erdős-Rényi graph

    (g) Define the Watts-Strogratz model

    (h) Define the Barabási-Albert model

    (i) Define the Page rank algorithm

    (j) What is the difference between failure and attack on networks?

8. Clustering, modularity, community detection

    (a) Difference between strict, overlapping, and hierarchical clustering

    (b) Modularity: definition

    (c) Modularity: algorithm

    (d) k-means clustering: defition and algorithm

    (e) Hierarchical clustering: definition. What are complete- and single-linkage

    (f) Clique percolation: definition

    (g) Define the Huffman coding

    (h) Infomap: main idea coding principles

    (i) Describe the algorithm for finding connected components on a graph

9. Algorithmically defined models

    (a) Self-Organized Criticality: definition

    (b) Bak-Tang-Wiesenfeld: definition

    (c) Bak-Sneppen model of evolution: definition

    (d) Nagel–Schreckenberg model: definition

    (e) Flocking model: definition

    (f) Define the minority models with memory. What is a strategy?

    (g) Describe the different phases of the minority model

10. Game models

    (a) Game models: Prisoner's dilemma, chicken game

    (b) Prisoner's dilemma: multiple agents: Strategies