PHYS580 Lab 11, October 31, 2019

Assignment: today's lab activity is to perform Monte Carlo simulations of the Ising model (Chapter 8 in the textbook) on a 2D square lattice with periodic boundary conditions.

1. Use the starter programs *ising.m* and *calculate_spin.m* (or your own equivalent routines) to simulate the Ising ferromagnet. First, try a small square grid (e.g., 10×10 or 15×15) to see how these programs work. Then, turn graphics off* for speed and do production runs on a bigger lattice, say, 50×50 (or even larger), at temperatures T sampled in regular increments both above and below $T_C \approx 2.27$ (measured in units of J/k_B), for a few different values of the magnetic field H (measured in units of J/μ). Make sure to calculate for $H = 0$, as well as positive and negative H. For initial conditions, you can try, e.g., having all spins up. Observe and note how the magnetization per spin (m) and energy per spin (E) converge towards their equilibrium values, as well as the qualitative features of the equilibrium configurations that may be reached. For example, check how the rate of convergence depends on the temperature and/or the field.

   * Use the lattice plots of red (up) and blue (down) sites displayed by the codes to get an idea of how the spin updates proceed, but later do turn the graphics off for faster calculations. A few hundred MCS per spin should suffice to see the trends in most (but not necessarily all) cases. Here, "trends" refers to the following: duration of the initial transient, time needed for an accurate average in equilibrium, and the magnitude of fluctuations.

2. Now modify your program such that it reads an additional *transient duration* parameter and then calculates the *means* of the magnetization and energy together with the *standard errors of the means* over a given number of MCS per spin *after* the transient. Plot the magnetization and energy (with errors) as a function of temperature over a range of T around T_C, with magnetic field set to a very small positive value $H = 0^+$ (this should help tame fluctuations). Set the duration of the transient and the number of MCS per spin over which to take the mean/fluctuation based on your observations from (1). Note any similarities and differences between m vs T for the Ising magnet and $P(p)$ vs p in percolation.