

## Tutorial 7

# Monte Carlo: The Ising model

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## 1 Description

The code used for this tutorial is a simulation of Ising model in a quadratic 2d area of variable length with external magnetic field switched off ( $H=0$ ). The Ising model is an area of spins which point either up or down. Nearest neighbor interaction is assumed (i.e. each spin has 4 neighbors), with a periodic boundary conditions. The moves are local ones which can be updated according to the Metropolis algorithm.

The answer of the questions of "Homeworks" should be send to the email address below this page in two weeks.

## Tasks

1. As a first task you are required to understand the global arrangement of the code, and write and complete the function *evaluate\_mc\_step()* that implements the Metropolis update on one spin. This part is marked in the code for you. The Metropolis update require that a

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move (spin flip) is accepted either if the energy of the system becomes lower, or in case of an energy increase, if the Boltzmann factor

$$\exp[-\beta(E_{after} - E_{before})]$$

is larger than a drawn random number between 0 and 1.

## 2 Inspection

After finishing the modification, compile the code:

```
>gcc ising.c -o ising -lgsl -lgslcblas
```

Then you have to run the code. You may give the code the values of parameters at the time of running. To know which parameters you should give just simply run: `./ising`.

*Remark* The parameter that you should give as the arguments are temperature, number of sweeps, the lattice size, hot case (which means the initial spin configurations are random ) or cold case ( which means the initial configurations are parallel) and the last parameter is the number of dumping image from the configuration.

*Hint:* The cold case can be given with a 0 value and hot case with a 1 value to the code.

### Tasks

1. Start to run the code for the number of sweeps "n-sweep=1000" and lattice size  $L=500$  for the temperature value  $T=0.6$ . The outcome you receive are few numbers which the first one is the magnetization  $m$ . The second and the third value are averaged magnetization  $\langle m \rangle$  and squared one  $\langle m^2 \rangle$  respectively. You also receive the snapshots of the images. Set the number of dumping image to 10 and try to animate the movie.

*Remark:* Look at the 'dump.\*.ppm' files with `display`, or animate the sequence using `>animate -delay 10 *.ppm`.

The snapshots should be similar to what is shown in figure 1, displaying domains in the proximity of the phase transition, and random magnetization at higher temperatures.

### Homework 1 (6 points)

1. Explain what do you observe in the movie you provided in the task above.. Repeat the procedure for increasing temperature. Try  $T=1.3, T=2.1$ . What do you observe now.
2. With the data file you get, you can sketch the magnetization as a function of time in the magnetization.dat. Make a plot of the magnetization as function of time for  $T=0.6, T=1.3, T=2.1$ . Explain what do you observe.

3. Collect the averaged magnetization that you get for several values of temperature from  $T=0.6$  to  $T=3.0$ . Make a plot of magnetization as a function of temperature out of the data. Explain what you observe. At which temperature the phase transition happens.
4. Repeat the tasks in the number 2 and 3 above for a lattice size of 20. What is difference you would observe.

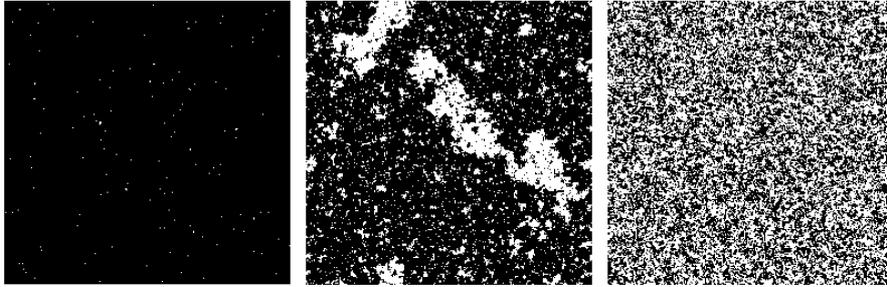


Figure 1: Configuration snapshots at three different values of temperature

### Homework 2 (4 points)

1. Now switch the initial configuration to the hot case by giving 1 for this parameter to the code. Run the code for the `n-sweep=1000` and `Lattice-size=100` and temperature  $T=0.4$ . Repeat the run with the same parameters again. Observe the values of magnetization. Do you see the same values, explain why?
2. make a movie like the homework before and observe what do you see here and explain it.
3. Make a plot for few values of temperatures for magnetization and explain what you see.