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2D Ising Model using Metropolis algorithm

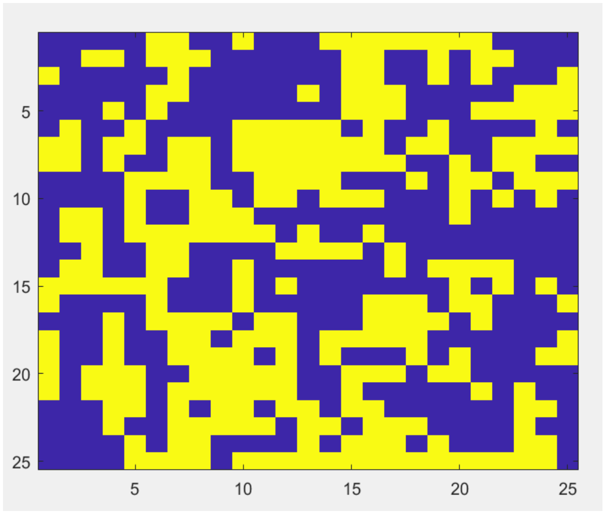
Ising_Shubham.m

```
%  ======================================================================
%              Two-dimensional Ising model
%    Phase Transition from paramagnetism to ferromagnetism
%  ========================================================================

% In this model we take value Kb=1 and J=1
clear all;
close all;

n = 25;  %No of lattice points.
m= ones(n); % forming a intital lattice of all spin up.

iter = 200; % no. of iterations.

% Boundary condition for positive and negative x,y axis
px(1:n)=(1:n)+1; px(n)=1;
nx(1:n)=(1:n)-1; nx(1)=n;
py(1:n)=(1:n)+1; py(n)=1;
ny(1:n)=(1:n)-1; ny(1)=n;

%forming empty arrays for different values.
eng=[];
neigh=[];
avg_eng=[];
Cv=[];
sus=[];

%set initial and final temperature
in_temp = 1;
en_temp = 5;

%initiating the loop with temperature difference 0.01
for t=en_temp:-0.01:in_temp
    for hh =1:iter           %loop for no. of iteration perform
        for i=1:n            %loop for lattice site i
            for j=1:n        %loop for lattice site j
                neigh(i,j) = m(px(i),j)+m(nx(i),j)+m(i,py(j))+m(i,ny(j));
%calculating the sum of all the neighbour of lattice site (i,j).
                dE = 2*neigh(i,j)*m(i,j);
%calculating the change in energy.

%                  =======================
                    %metropolis algorithm
%                  =======================

                r=rand();                                   % generating a random
number.
                if dE <0 || exp(-dE/t)>r                    % checking if change in
energy is less than zero or random no. generated is less than boltzmann factor.
                m(i,j)=-m(i,j);                             % if above statement is
true then flip the spins.

                end
            end
        end
```

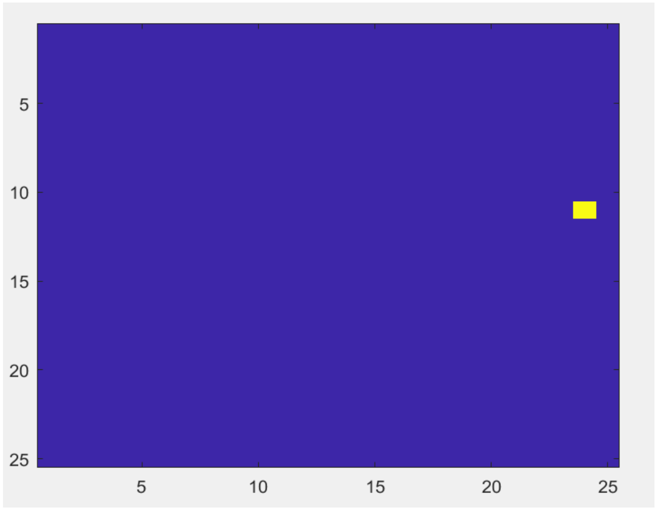
```
    end
    figure(1);
    imagesc(m)
    pause(0.00000000001)
eng=-0.5*(m.*neigh);                                          %cal the energy
avg_eng = mean(eng,'all');                                    %cal the average energy
avg_mag = sum(m,'all')/(n^2);                                 %cal the average
magnetisation
mag = sum(m.*m,'all')/(n^2);                                  %cal the magnetisation
Cv = (mean((eng.*eng),'all')-(avg_eng.*avg_eng))/(t*t);          %cal the specific
heat
sus=(mean((mag.*mag),'all')-(avg_mag.*avg_mag))/(t);             %cal the magnetic
susceptibility

%Plotting the Average Energy,Average Magnetisation,Specific Heat,Magnetic
%Susceptibilty w.r.t Temperature
figure(2);
subplot(2,2,1);
plot(t,avg_eng,'r*');title('Average energy Vs
Temperature');xlabel('Temperature');ylabel('Average energy');
hold on;
subplot(2,2,2);plot(t,avg_mag,'g*');title('Average Magnetisation Vs
Temperature');xlabel('Temperature');ylabel('Average Magnetisation');
hold on;
subplot(2,2,3);plot(t,Cv,'b*');title('Specific Heat Vs
Temperature');xlabel('Temperature');ylabel('Specific Heat');
hold on;
subplot(2,2,4);plot(t,sus,'k*');title('Susceptibility Vs
Temperature');xlabel('Temperature');ylabel('Magnetic Susceptibility');
hold on;

end
```

Snapshots

(25x25 square lattice)

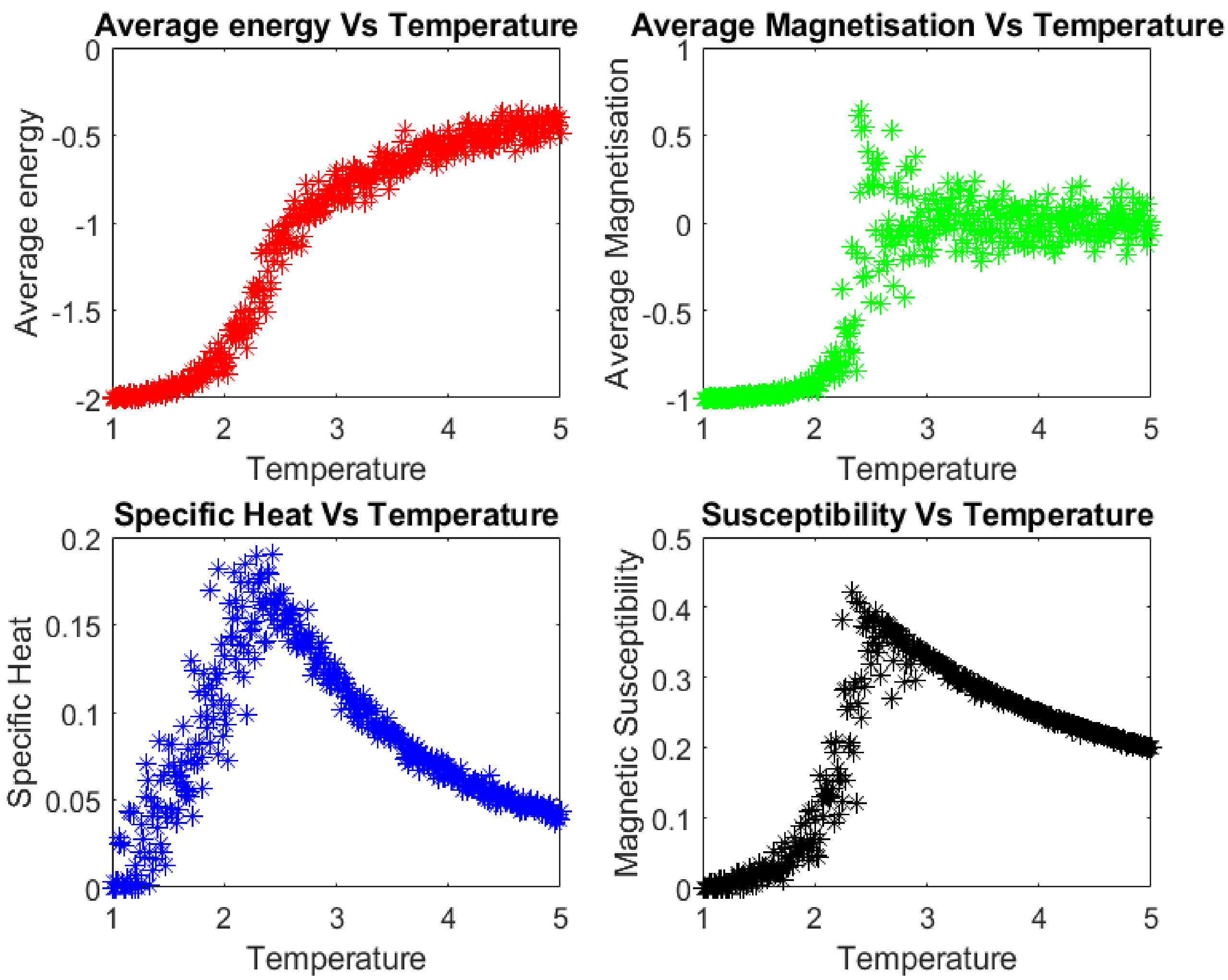


Paramagnet (above Curie temperature)



Ferromagnet (below Curie temperature)

Plots



Analysis

Using Metropolis algorithm on 25x25 square lattice I plotted the corresponding observables for 200 iterations for initial temp = 1 to final temp =5 with temperature difference of 0.01.

As we can see from the above graph for Magnetisation and temperature, magnetisation suddenly drops for a definite temperature (i.e. Curie temperature Tc) which shows the phase transition from paramagnetic phase to ferromagnetic phase.

From graph it is evident that energy is the continuous function of temperature.

Acc. to 2^{nd} order phase transition specific heat and magnetic susceptibility are discontinuous at curie temperature(Tc).

All above explanation proves 2D Ising Model having phase transition from paramagnetic phase to ferromagnetic phase.