MONTE CARLO SIMULATIONS OF THE PHASE TRANSITION IN MAGNETS

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ABSTRACT

The goal of this research project is to use the Metropolis Algorithm in Monte Carlo to simulate phase transitions in magnets from a one-dimensional perspective. Understanding the Metropolis Algorithm is accomplished by a side project on "computation of π" in MATLAB. The numerical value of π is obtained by calculating the area under the curve of a circle function with randomly placed dots. This approach is then applied to the n-site Ising Model, and the code is validated using bar charts. To calculate the average magnetization, the magnetization of each configuration is created. Objects are less likely to become magnets in the one-dimensional Ising Model. Furthermore, the magnetic susceptibility is graphed versus temperature, indicating that the susceptibility decreases as temperature increases in this model.

INTRODUCTION

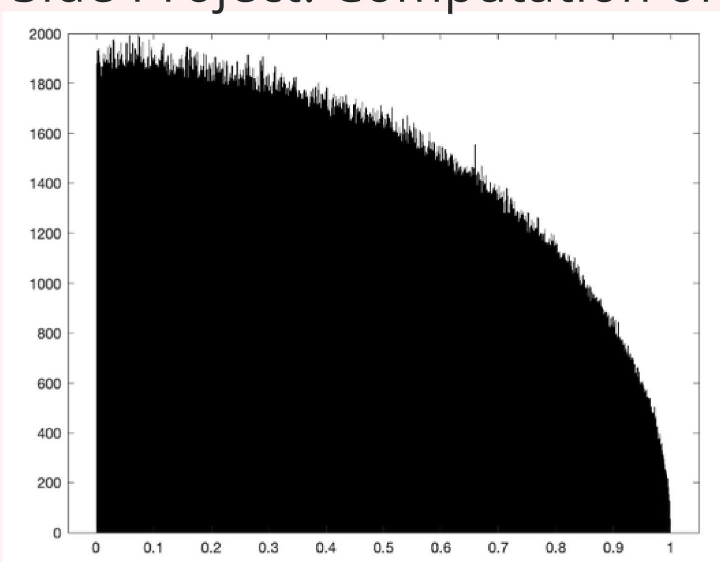
Magnets are made up of atoms aligned in the same direction, resulting in the north and south poles. Magnets can lose their magnetism during phase transitions caused by temperature changes. The atoms in the Ising Model are represented in a lattice structure with spins that indicate their orientation (+1 for up, -1 for down) (Tong, 2017). All spins align to produce a pattern when magnetized. We investigate spin probability changes with temperature using the Metropolis Algorithm in Monte Carlo. Magnetization (m) is calculated using Mean Field Theory (MFT) by obtaining the mean spin value in the lattice. This method enables us to study magnets' spin behavior, magnetization, and magnetic susceptibility as temperature changes (Shankar, 2018).

METHODOLOGY, RESULTS, AND DISCUSSIONS

Metropolis Algorithm:

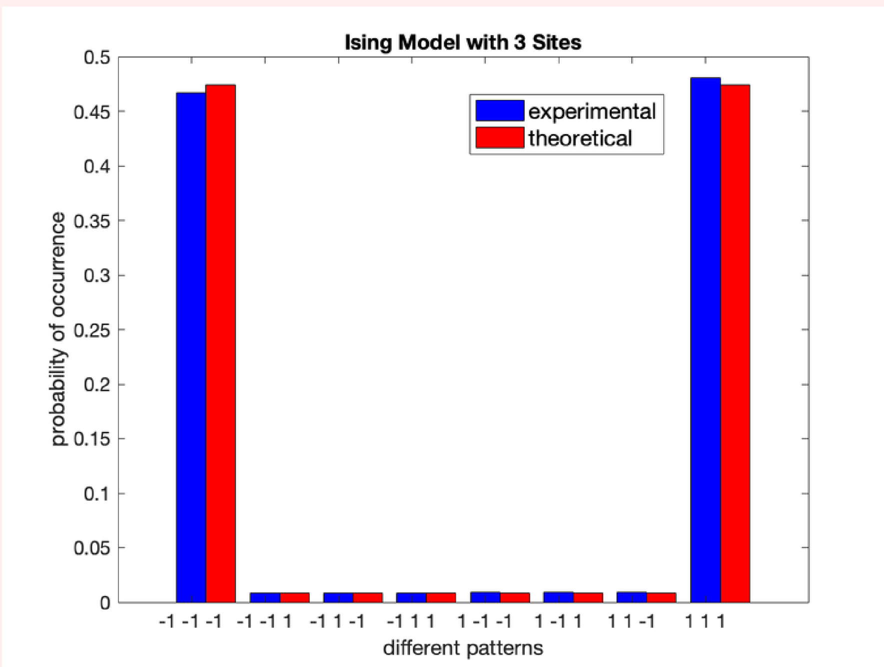
1. Generate a random number i, calculate p(i)
2. Purpose a change j: p(i) < p(j) => accept; else: acceptance rate - p(j)/p(i)
3. Repeat step 2 and get a sequence of i

Side Project: Computation of π

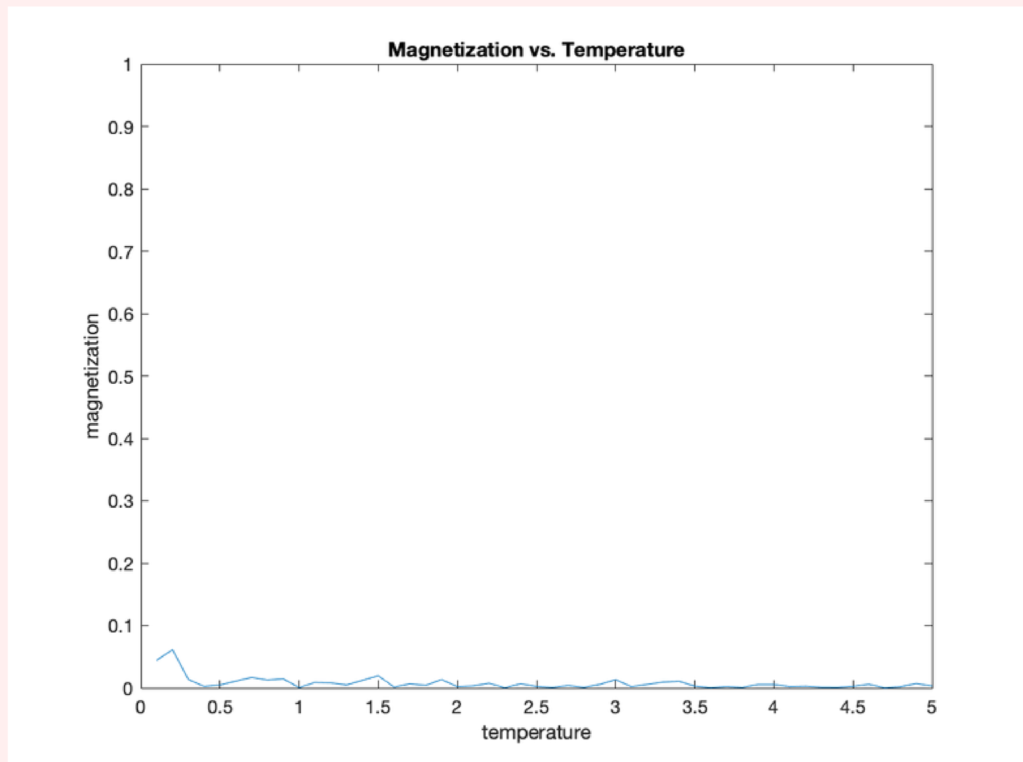


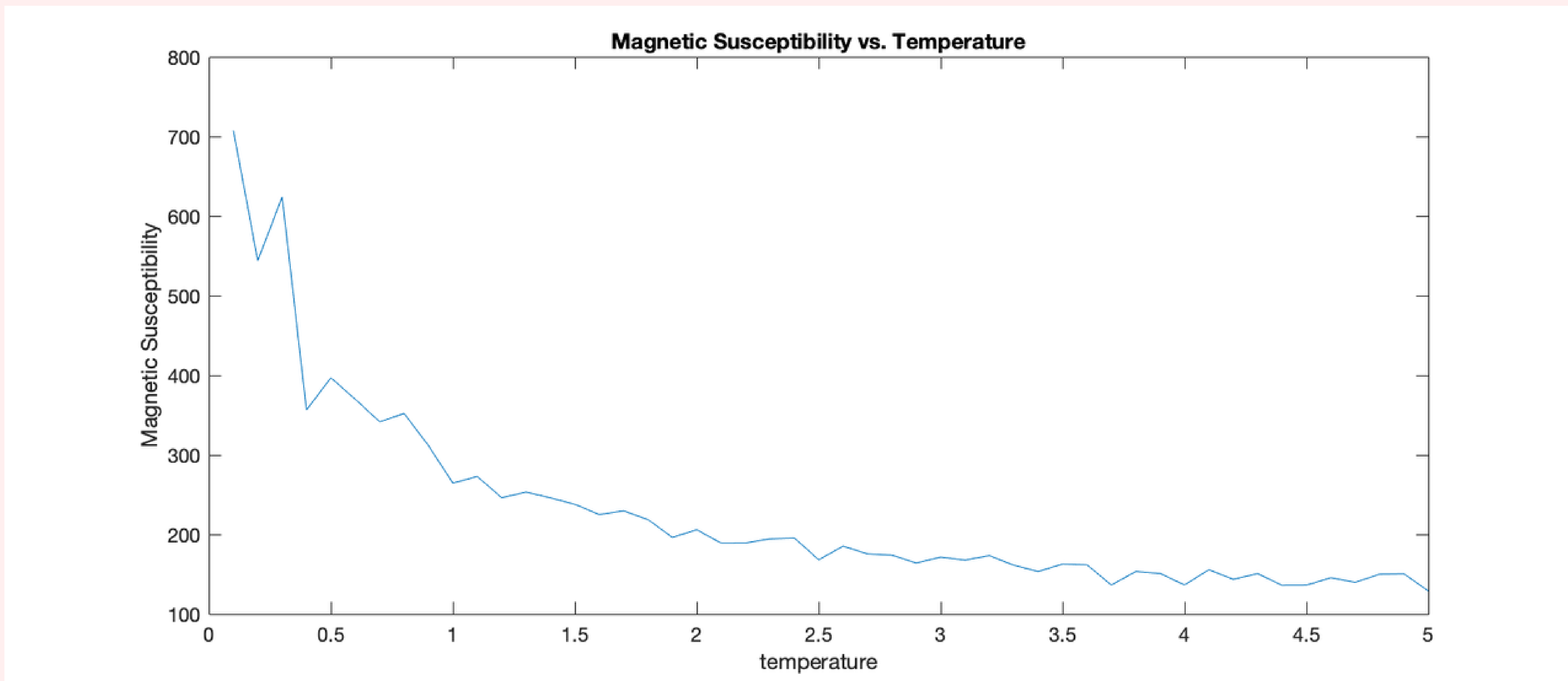
Command Window

```
>> MetropolisComputingpi

approximationofpi =

    3.1416
```



The algorithm is implemented correctly. For Ising Models with N sites, the experimental data and the theoretical data are similar and comparable.





As shown on the graph on the left side, the magnetizations of an object are very low and are almost 0, which means under all temperatures, when a magnet is brought near to an object, the object will get magnetized but will not be able to retain its magnetism.

Magnetic susceptibility shows that as the temperature increases, the object is less likely to be influenced by external magnetic fields and will be harder to get magnetized by induction.

Under the log scale, the calculated slope is -0.4, which means the magnetization is 1/T^0.4 while MFT: 1/(T+2)

CONCLUSION AND FUTURE WORK

- Mean Field Theory does not apply to the 1-dimensional Ising Model
- In the 1-dimensional Ising Model, objects are not very likely to become a magnet under all temperatures and are hard to retain their magnetism after being magnetized by induction.

FUTURE WORK: conduct simulations on 2 or more dimensional Ising Models

REFERENCES

Shankar, R. (2018). *Quantum Field Theory and Condensed Matter: An Introduction*. Cambridge University Press.

Tong, D. (Presenter). (2017). *Statistical Field Theory*. Lecture presented at University of Cambridge, Cambridge, United Kingdom.