

```
In [1]: import Pkg
Pkg.add("DataStructures")
Pkg.add("Shuffle")
Pkg.add("Plots")
Pkg.add("Distributions")
Pkg.add("Random")
using DataStructures
using Shuffle
using Plots
using Random
using Distributions

#takes in an integer n
#returns array of length n of integers +/- 1 (randomly chosen) that represent spins
function initial_config(n::Int)
    config = zeros(n)
    if n%2 != 0
        println("Size n must be even.")
        return
    else
        for i=1:n
            config[i] = rand([-1, 1])
        end
    end
    #print(config)
    return config
    #essentially from N, we get a randomized array of spin ups and downs
    #e.g., N=2 may equal [1,-1]; N=4 may equal [1,-1,-1,1] as our initial configuration
end

function gaussian_rf(N)
    nd = Normal(0, 1)
    return rand(nd, N)
end

function unit_rf(N)
    field = zeros(N)
    for i=1:N
        field[i] = rand([-0.5, 0.5])
    end
    return field
end

#standard function for getting the hamiltonian of 1/r^2
#Ising Model
function get_energy(s::AbstractArray, h::AbstractArray, J)
    E0 = 0.0
    E1 = 0.0
    E2 = 0.0
    for i=1:length(s)
        #if i != length(s)
        #E0 += J*s[i]*s[i+1]
        #else
        #E0 += J*s[i]*s[1]
        #end
        for j=i:length(s)
            if j != i
                E1 += J*(s[i]-s[j])^2/(i-j)^2
            end
        end
        E2 += h[i]*s[i]
    end
    E = -E1/2 - E2
    return E
end

#magnization equals the summation of spins in
#a configuration.
#magnetization per spin = <M>/N, where
#N is basically length of the configuration
function get_magnetization(config::AbstractArray)
    M = sum(config)
    return M
end

function get_susceptibility(M_list, Msq_list, kT, N)
    avg_M = 0
    #avg_M = sum(M_list)/mcsteps
    avg_Msq = sum(Msq_list)/mcsteps
    X = (1/kT)*(avg_Msq - avg_M^2)/N
    return X
end

function do_MC_Step(config, kT, J, h, M_list, Msq_list)
    N = length(config)
    E = get_energy(config, h, J)
    for i=1:N
        site = rand(1:N)
        config[site] = -1*config[site]
        #attempt to update one site of the configuration
        E_new = get_energy(config, h, J)
        #look at the hamiltonian of the configuration
        #given this updated site
        dE = E_new - E
        #look at the difference between old and new hamiltonian
        prob = exp(-dE/(kT))
        #Metropolis acceptance ratio
        r = rand(Float64)

        if min(1, prob) > r
            #if true, configuration is "updated"
            #accepted_states += 1
            E += dE
        else
            config[site] = -1*config[site]
            #if false, then configuration stays the same
        end
    end
    M = get_magnetization(config)
    M_sq = M^2
    #println("M squared: ", M_sq)
    #push!(M_list, abs(M))
    push!(Msq_list, M_sq)
    #we get the magnization per spin of the updated system
end

function metropolis(config_initial::AbstractArray, kT, J, h, mcsteps)
    config = copy(config_initial)
    #starts out with a configuration of randomized N spin array
    mags = Vector{Float64}()
    square_mags = Vector{Float64}()
    M = get_magnetization(config)
    push!(mags, M)
    push!(square_mags, M^2)

    accepted_states = 0
    #initial state of the configuration before a MCMC update
    E = get_energy(config, h, J)
    # hamiltonian of a particular configuration
    for i=1:mcsteps
        #For MCMC an arbitrary number steps are executed for precision
        do_MC_Step(config, kT, J, h, mags, square_mags)
    end
    return mags, square_mags
end

#CONSTANTS:

#Number of spins in initialized configuration
N = 1000

#Interaction constant
J = 1.0

#Initialize number of montecarlo steps
mcsteps = 10000

config0 = initial_config(N)

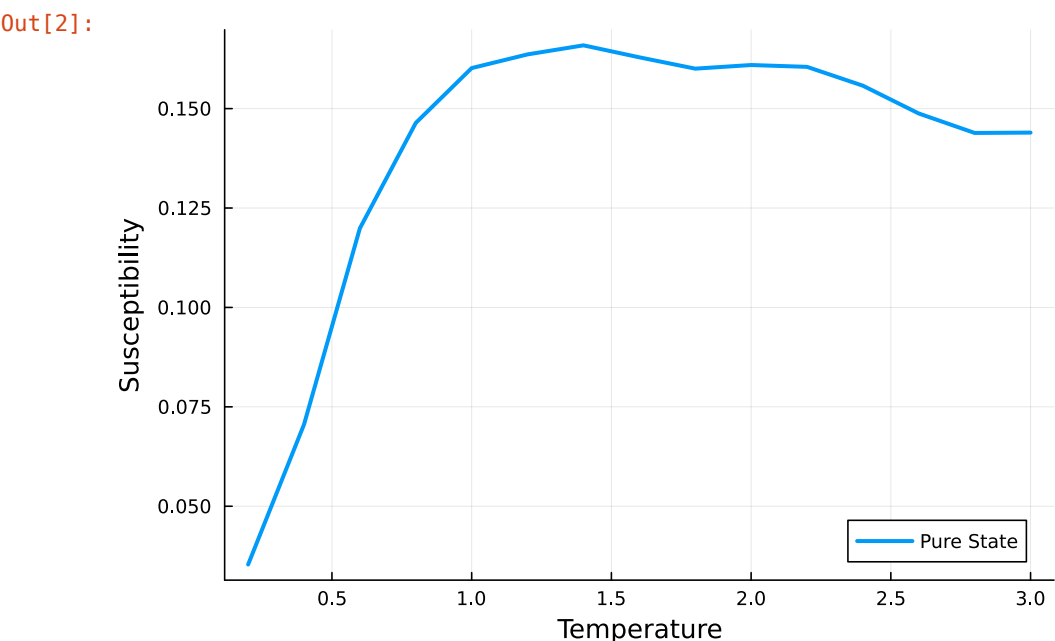
#Initialize random field(s)
h1 = unit_rf(N)
h2 = gaussian_rf(N)
h3= zeros(N) #PURE STATE

initkT = 0.2
iter = 0.2
finalkT = 3.0
```

```
Updating registry at `~/.julia/registries/General.toml`
Resolving package versions...
No Changes to `~/.julia/environments/v1.8/Project.toml`
No Changes to `~/.julia/environments/v1.8/Manifest.toml`
Resolving package versions...
No Changes to `~/.julia/environments/v1.8/Project.toml`
No Changes to `~/.julia/environments/v1.8/Manifest.toml`
Resolving package versions...
No Changes to `~/.julia/environments/v1.8/Project.toml`
No Changes to `~/.julia/environments/v1.8/Manifest.toml`
Resolving package versions...
No Changes to `~/.julia/environments/v1.8/Project.toml`
No Changes to `~/.julia/environments/v1.8/Manifest.toml`
Resolving package versions...
```

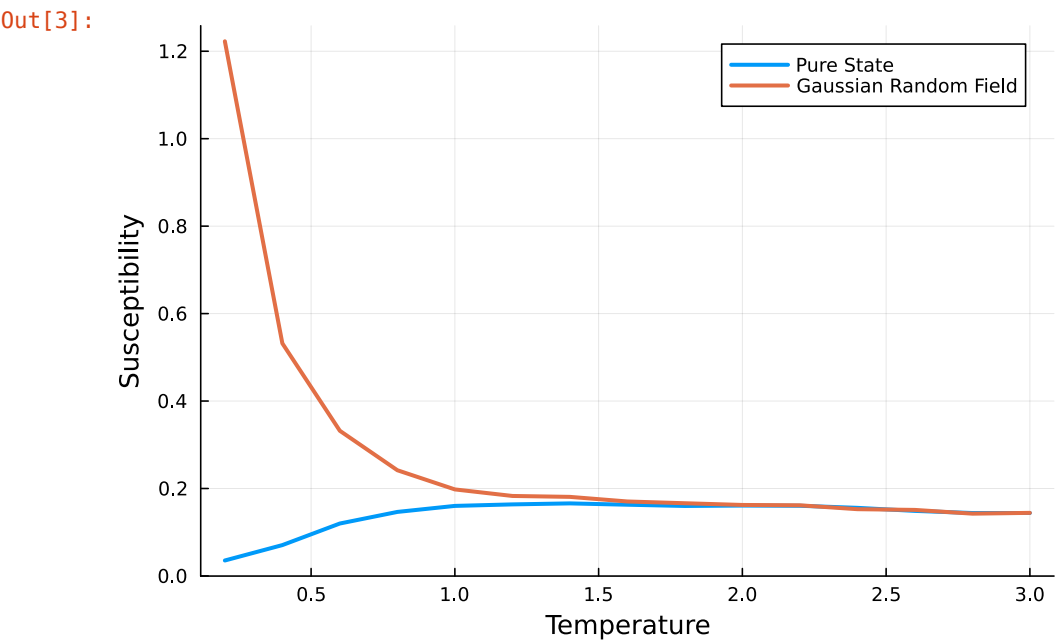
```
In [2]: #Pure State:
@time begin X_list1 = Vector{Float64}()
for kT = initkT:iter:finalkT
    println("At ", kT, " kT.")
    data = metropolis(config0, kT, J, h3, mcsteps)
    X = get_susceptibility(data[1], data[2], kT, length(config0))
    push!(X_list1, X)
end
plot(initkT:iter:finalkT, X_list1, xlabel = "Temperature", ylabel = "Susceptibility")
end

At 0.2 kT.
At 0.4 kT.
At 0.6 kT.
At 0.8 kT.
At 1.0 kT.
At 1.2 kT.
At 1.4 kT.
At 1.6 kT.
At 1.8 kT.
At 2.0 kT.
At 2.2 kT.
At 2.4 kT.
At 2.6 kT.
At 2.8 kT.
At 3.0 kT.
193510.523665 seconds (4.43 M allocations: 245.146 MiB, 0.00% gc time, 0.00% compilation time: 22% of which was recompilation)
```



```
In [3]: #Gaussian Random Field:
@time begin X_list2 = Vector{Float64}()
for kT = initkT:iter:finalkT
    println("At ", kT, " kT.")
    data = metropolis(config0, kT, J, h2, mcsteps)
    X = get_susceptibility(data[1], data[2], kT, length(config0))
    push!(X_list2, X)
end
plot(initkT:iter:finalkT, X_list2, xlabel = "Temperature", ylabel = "Susceptibility")
end

At 0.2 kT.
At 0.4 kT.
At 0.6 kT.
At 0.8 kT.
At 1.0 kT.
At 1.2 kT.
At 1.4 kT.
At 1.6 kT.
At 1.8 kT.
At 2.0 kT.
At 2.2 kT.
At 2.4 kT.
At 2.6 kT.
At 2.8 kT.
At 3.0 kT.
170957.952665 seconds (335.45 k allocations: 22.476 MiB, 0.00% compilation time)
```



```
In [17]: print(X_list2)

[0.25007999999999997, 0.28896, 0.24372000000000005, 0.23897, 0.223208, 0.218373, 0.2132457142857143, 0.201125, 0.19762666666666667, 0.19142399999999998, 0.17792727272727274, 0.18039666666666668, 0.1668, 0.16540285714285716, 0.15995199999999998]
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In [ ]:
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