Minimize to Remember

2012 Skadron Prize In Computational Physics

A model for a network of neurons (*i.e.*, nerve cells) inside a brain can mimic a process of associative memory (*i.e.*, associating or matching a given input pattern with a memorized pattern, for example, a photographic image of your parents with their image memorized in your brain). In this model, this memory process is represented by a process of minimizing the following function:

$$H\left(\{S_1, S_2, S_3, ..., S_N\}\right) = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N}J_{ij}S_iS_j$$

by varying N variables, S_1, S_2, S_3, ..., and S_N.

Each variable S_i represents the state of the i-th neuron:

$S_i = +1$, if the neuron is excited and firing electrical signals to other neurons,

and

$S_i = -1$, if the neuron is not excited.

J_{ij} prescribes how the j-th neuron affects the i-th neuron: J_{ij} is roughly proportional to an electrical potential change in the i-th neuron when the j-th neuron is firing electrical signals to the i-th neuron. J_{ij} also satisfies

$$J_{ii} = 0 \qquad \text{and} \qquad J_{ij} = J_{ji}.$$

We will assign each J_{ij} one of the following two values:

$$J_{ij} = +1 \text{ or } -1.$$

If the value for each J_{ij} is chosen randomly between these two values, then there may be many ways of assigning a value, either +1 or –1, to each S_i that minimize the above function H.

For this year's Skadron prize, we ask you to create a FORTRAN subroutine that finds one of these minimum values. The goal is therefore to find the value of each S_i that minimizes H when the value of each J_{ij} is randomly selected by the main program, which will be provided by the department.

Challenge

Write a FORTRAN subroutine "minimize.f" that must start with the following 2 lines:

subroutine minimize (IS, Jij, N)
integer:: IS(N), Jij(N, N)

where

IS is an integer array variable whose size is N, the total number of the neurons. IS(i) represents S_i and takes a value of either +1 or –1;

Jij is a two-dimensional integer array variable whose size is N by N. Jij(i, j) represents J_{ij} and takes a value of either +1 or –1. The value of each Jij is randomly assigned by the main program.

For the contest, we will use the following value for N:

N = 1000.

However, your subroutine should run for any arbitrary value of N.

The Prize committee will run your subroutine "minimize.f" with the main program, which checks if the value for each S_i selected by your subroutine is either +1 or –1. Your subroutine will be given three sets of J_{ij} and the main program calculates the function H for these three sets. The first prize goes to the contestant whose subroutine gives the lowest "average" value for H. Your subroutine must also complete its computation for the three sets of J_{ij} within 5 minutes.

CAUTION: do not attempt to examine every possible way of assigning values to S_i to find the one with the lowest value for H, because it will certainly take more than 5 minutes.

To test your subroutine "minimize.f" on our computer "meitner":

1. Copy the main program "skmain12.f" on "meitner" to your account on "meitner":

cp ~hmb/hmb/skmain12.f skmain12.f

2. Compile and run your subroutine with the main program:

g95 skmain12.f minimize.f
a.out

Prizes: $ 200 for the first place; $100 for the second place. The winners will be announced at the annual physics department award ceremony on Tuesday, April 17, 2012.

Who can participate: Physics majors at ISU.

Deadline: submit your subroutine by attaching it to an email addressed to

hmb@phy.ilstu.edu

by noon on Tuesday, April 10, 2012.