****

- AUTHOR(S) :
- Bruno González Soria (A01169284)
- Antonio Osamu Katagiri Tanaka (A01212611) *
- FILENAME :
- HW03.m *
- DESCRIPTION :
- Computación Aplicada (Ene 19 Gpo 1)
- Final Exam *
- NOTES :
- In submitting the solution to this final exam, We Bruno González
- Soria and Antonio Osamu Katagiri Tanaka affirm our awareness of the
- standards of the Tecnológico de Monterrey Ethics Code. *
- START DATE :
- 02 May 2019

Contents

****

This script should start with the command rng(31416), and should not contain any other call that initializes the state of the random number generator.

```
close all, clear all, clc, format compact
rng(31416)
```

****

Problem 1: OPTIMIZATION Consider the following function:

```
           ____6___                 2
           \      /          18  / ixi \
   f(X) =   \        sin(xi) sin   | ----- |
            /                    \  Pi /
           /_______\
              i=1
```

where 0 < xi < 5.

Maximize function f () using the Nelder-Mead algorithm (fminsearch) and simulated annealing (simulannealbnd). Modify whatever parameters you deem necessary to produce a good performance of these algorithms, regardless of the state of the random number generator. Use randomly generated initial point in the valid range of x.

****

```
a) Implement f (x) as a MATLAB function.
```

```
i = 1:6;
f = @(x) -fx(x);
```

****

```
b) Give your best solution found (optimal x and evaluation of x) for
each algorithm.
```

```
% NelderMeade
x0 = rand([1 6])*5;
options = optimset('Display', 'off', 'MaxFunEvals', 10000);
disp("The optimal value of x usning NelderMeade (fminsearch) method is:")
[x,fval,exitflag,output] = fminsearch(f,x0,options)

% Simulated Annealing
disp("The optimal value of x usning Simulated Annealing (simulannealbnd) method is:")
lb = zeros([1 6]);
ub = ones([1 6])*5;
[x,fval,exitflag,output] = simulannealbnd(f,x0,lb,ub,options)
```

```
The optimal value of x usning NelderMeade (fminsearch) method is:
```

****

```
c) Which of these two algorithms has a better expected performance on
this problem when varying the initial point(s)? Justify your answer.
```

```
% From this two algorithms, fminsearch has a better expected performance on
% this problem. The reason is that the fval (objective function value at
% the solution) obtained is larger than the one obtained in simulannealbnd,
% thus closer to a maximum in the function. Additionally, unlike other
% solvers, fminsearch stops when it satisfies both TolFun and TolX.
```

****

DEFINED FUNCTIONS:
Problem 1 a)

```
function fcn = fx (x)
suma=0;
    for i = 1:6
        newterm = sin(x(i))*sin((i*x(i))^2/pi)^18;
        suma = suma + newterm;
    end
    fcn = suma;
end
```

```
x =
    4.4463    1.1141    4.6886    0.0604    0.9936    0.0606
fval =
   -1.7347
exitflag =
     1
output =
  struct with fields:

    iterations: 786
     funcCount: 1297
     algorithm: 'Nelder-Mead simplex direct search'
       message: 'Optimization terminated:↵ the current x satisfies the termination criteria using OPTIONS.TolX of 1.000000e-04 ↵ and F(X) satisfies the conver
The optimal value of x usning Simulated Annealing (simulannealbnd) method is:
x =
    0.8269    2.4652    3.4183    1.2366    1.6021    2.7953
fval =
   -2.7718
exitflag =
     1
output =
  struct with fields:

     iterations: 6009
      funccount: 6166
        message: 'Optimization terminated: change in best function value less than options.FunctionTolerance.'
       rngstate: [1×1 struct]
    problemtype: 'boundconstraints'
    temperature: [6×1 double]
      totaltime: 1.6105
```

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```

**

Problem : INTEGER PROGRAMMING

An airline company is considering the purchase of new long-, medium-, and short-range jet passenger airplanes. The purchase price is $33.5M for each long-range plane, $25M for each medium-range plane, and $17.5M for each short-range plane. The board of directors has authorized a maximum of $750M for these purchases. Regardless of which planes are purchased, air travel of all distances is expected to be sufficiently large enough so that these planes would be utilized at essentially maximum capacity. It is estimated that the net annual profit (after subtracting capital recovery costs) would be $2.1M per long-range plane, $1.5M per medium-range plane, and $1.15M per short-range plane.

Enough trained pilots are available to the company to crew 30 new airplanes. If only short-range planes were purchased, facilities would be able to handle 40 new planes. However, each medium-plane is equivalent to 1+1/3 short-range planes, and each long-range plane is equivalent to 1+2/3 short-range planes in terms of their use of maintenance facilities. Using the preceding data, management wishes to know how many planes of each type should be purchased to maximize profit.

**

a) Formulate the problem as an integer programming problem.

```
Let L be the number of long-range jets to buy
Let M be the number of medium-range jets to buy
```

```
Let S be the number of short-range jets to buy
And let P the profit

Maximise P = 2.1*L + 1.5*M + 1.15*S

Subject to: 33.5*L + 25*M + 17.55*S <= 750
            L + M + S <= 30
            1.67*L + 1.33*M + S <= 40
            L >= 0, M >= 0, S >= 0
            L, M, S are integers
```

b) Use intlinprog to find the solution (number of planes of each type and maximum profit)

```
l = optimvar('L','Type','integer');
m = optimvar('M','Type','integer');
s = optimvar('S','Type','integer');
prob = optimproblem('ObjectiveSense','maximize');
prob.Objective = 2.1*l + 1.5*m + 1.15*s;
prob.Constraints.cons1 = 33.5*l + 25*m + 17.55*s <= 750;
prob.Constraints.cons2 = l + m + s <= 30;
prob.Constraints.cons3 = (5/3)*l + (4/3)*m + s <= 40;
prob.Constraints.cons4 = l >= 0;
prob.Constraints.cons5 = m >= 0;
prob.Constraints.cons6 = s >= 0;

options = optimoptions('intlinprog','Display','off');

sol = solve(prob);
disp(sol);
```

```
LP:                Optimal objective value is -47.811912.

Heuristics:        Found 1 solution using rounding.
                   Upper bound is -46.650000.
                   Relative gap is 2.44%.

Cut Generation:    Applied 1 mir cut.
                   Lower bound is -47.809396.
                   Relative gap is 2.43%.

Branch and Bound:

   nodes     total   num int        integer       relative
explored  time (s)  solution           fval        gap (%)
       2      0.00         2  -4.780000e+01   1.223065e-12

Optimal solution found.

Intlinprog stopped because the objective value is within a gap tolerance of the
optimal value, options.AbsoluteGapTolerance = 0 (the default value). The intcon
variables are integer within tolerance, options.IntegerTolerance = 1e-05 (the
default value).

    L: 14.0000
    M: 0
    S: 16
```

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- Thanks to The Coding Train: https://www.youtube.com/watch?v=XJ7HLz9
- VYz0&list=PLRqwX-V7Uu6Y7MdSCaIfsxc561QI0U0Tb&index=1 *
- START DATE :
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```
close all, clear all, clc, format compact
rng(31416)
```

* Problem 3: LEARNING ***

The age of a specific species of shellfish is related to several physical characteristics. The sheet data of the Excel file shellfish.xlsx contains data of 4077 individuals, and their ages

```
% shellfish.xlsx data description:
% ---------------+------------+-------+---------------------------
% Name           | Data Type  | Meas. | Description
% ---------------+------------+-------+---------------------------
% Sex            | nominal    |       | M, F, and I (infant)
% Length         | continuous | mm    | Longest shell measurement
% Diameter       | continuous | mm    | perpendicular to length
% Height         | continuous | mm    | with meat in shell
% Whole weight   | continuous | grams | whole shellfish
% Shucked weight | continuous | grams | weight of meat
% Viscera weight | continuous | grams | gut weight (after bleeding)
% Shell weight   | continuous | grams | after being dried
% Age            | integer    |       | years
% ---------------+------------+-------+---------------------------
```

***

a) Train a neural network using the information of these 4077. 1) This data must be divided into training, testing, and possibly validation examples. Explain your decision when choosing these data sets.

```
The neural netowrk (AKA brain) is trained through a superviced
learning algorithm. Therefore the 4077 entries in shellfish.xlsx
are used for both purposes, training and testing. The reason
behind this desition is to consider the most amount of entries as
possible, therfore to train the brain with all the known data.
```

```
2) Explain any pre-processing done to the data.
```

```
Two steps were performed to pre-process the data: 1) convert the
imported cell-matrix data types into ordinary matrices, and
2) convert the categorical variables into integer values. These
convertions are done to ease the algorithm computation.
```

```
% load shellfish data
ssds = spreadsheetDatastore('./shellfish.xlsx');

% store the 1st sheet - DATA **********************************************
ssds.Sheets = 1;
data = read(ssds);
data_arr = zeros(height(data),width(data));

% convert cell matrix to ordinary matrix
for k=1:width(data)
   %data_varNames = data.Properties.VariableNames(k); %debuggin purposes
   %data_varNames = cell2mat(data_varNames); %debuggin purposes
    table_col = table2array(data(1:height(data),k));

    if isa(table_col,'cell')
        % convert categorical values to integers:
        % F = 70, M = 77, I = 73
        data_arr(1:height(data),k) = cell2mat(table_col);
    else % keep the values as they are
        data_arr(1:height(data),k) = table_col;
    end
end

% data_arr shall be used for the neural training

% let's train the brain/perceptron with the known training data in
% data_arr - Through a SUPERVISED LEARNING ALGORITHM
%    1) Provide the perceptron with inputs for which there is a known
%       answer
%    2) Ask the perceptron to guess an answer
%    3) Compute the error (Did it get the answer right or wrong?)
%    4) Adjust all the weights according to the error
%    5) Return to step 1) and repeat!

% initialize the weights randomly
nInputs = width(data)-1; % number of inputs
weights = zeros(1,nInputs);
for k=1:nInputs
    weights(1,k) = randi([-10 10]); % random numbers between -10 and 10
end
% from previous trainings, the weights are estimated to be the following:
weights = [-7.5340 5.6109 5.3689 6.3149 2.7319 -10.4802 7.2560 0.1472];

% let's create some variables to see how well brain is being trained
guess = zeros(1,length(data_arr)); % to store what the perceptron guesses
known = zeros(1,length(data_arr)); % to store the correct answers
```

```
n = 25; % let's train the brain n-times
for i=1:n
    for k=1:length(data_arr)
        % let's feed our brain/perceptron some intputs
        inputs = data_arr(k,1:width(data)-1);
        % set the known target (correct answer) to compute the error
        target = data_arr(k,width(data));
        % let's create a brain/neuron
        brain = perceptron(inputs,weights,target);
        % let's ask brain for a guess
        brain = brain.guess;
        % let's train the brain according to the previous guess
        brain = brain.train;
        % update the weights according to the training
        weights = brain.weights;
        % populate the tracking variables
        guess(1,k) = brain.Output;
        known(1,k) = brain.target;
    end
end

% Guesses are rounded to the nearest integer. Age is od type integer, as
% defined in shellfish.xlsx data description
guess = round(guess);
```

****

---

b) Using your trained neural network, determine the age of the 100 individuals in sheet predict. Write the results to as a column of an Excel worksheet.

```
The predicted data (ages) are stored in predictedAge
```

```
% store the 2nd sheet - PREDICT *******************************************
ssds.Sheets = 2;
predict = read(ssds);
predict_arr = zeros(height(predict),width(predict));

% convert cell matrix to ordinary matrix
for k=1:width(predict)
   %predict_varNames = predict.Properties.VariableNames(k); %debuggin purposes
   %predict_varNames = cell2mat(predict_varNames); %debuggin purposes
    table_col = table2array(predict(1:height(predict),k));

    if isa(table_col,'cell')
        % convert categorical values to integers:
        % F = 70, M = 77, I = 73
        predict_arr(1:height(predict),k) = cell2mat(table_col);
    else % keep the values as they are
        predict_arr(1:height(predict),k) = table_col;
    end
end

% data from predict_arr shall be used to predict the Age

% let's create a variable to store the predictions
predictedAge = zeros(length(predict_arr),1);

% let's guess predict_arr
for k=1:length(predict_arr)
    % let's feed our brain/perceptron some intputs to get a guess.
    inputs = predict_arr(k,1:size(predict_arr,2));
    % set the known target to 0 ... this is not used in this step
    target = 0;
```

```
    % let's create a brain
    brain = perceptron(inputs,weights,target);
    % let's ask brain for a guess
    brain = brain.guess;
    % populate the tracking variable
    predictedAge(k,1) = brain.Output;
end

% Predictions are rounded to the nearest integer. Age is od type integer,
% as defined in shellfish.xlsx data description
predictedAge = round(predictedAge);

% Save predictions into a CSV file
tbl = [predict array2table(predictedAge)];
writetable(tbl,'./cLearning.csv','WriteRowNames',true,'Delimiter',',');
disp(tbl)
```

Sex	Length	Diameter	Height	Whole	Shucked	Viscera	Shell	predictedAge
'M'	105	83	29	169	70.5	32.7	57.5	12
'I'	107	80	29	141	61.3	27.3	44	12
'M'	100	80	26	132.9	51.6	26.6	48	12
'I'	90	72	26	95.6	38.2	25.4	27.4	11
'I'	88	68	25	97.9	34.7	17.5	40	12
'M'	116	95	30	194	77	43.3	70	14
'I'	87	66	19	78.6	43.8	15	17.7	9
'M'	111	89	26	172.5	84.5	31	48	11
'F'	129	103	35	309.2	140.7	73	83	14
'I'	87	68	22	75.9	29.9	17	24	11
'I'	112	88	34	188.9	70.9	43.5	60	14
'M'	39	29	10	6.4	2	1.6	2.4	7
'I'	76	56	19	57.7	33	8.7	13.4	9
'I'	104	76	26	106.9	47.5	24.4	30.7	12
'F'	127	100	36	251.3	107.8	58.4	70	14
'I'	67	50	16	33.9	13.9	8.8	9.9	9
'F'	108	95	31	243.4	106.1	61.5	68	13
'M'	125	94	30	224.8	111.2	46.3	57.4	12
'M'	125	97	32	242.7	126.2	44.7	60.4	11
'M'	139	110	41	434.6	226.6	93.3	99.2	11
'I'	104	77	23	116.2	51.1	31.2	28.6	11
'I'	66	52	16	38	15.3	7.7	13	9
'M'	118	92	29	185.8	76	48	51	13
'M'	105	80	28	144.1	73.7	29	34.7	10
'I'	88	69	24	97.4	39.3	21.6	32	11
'F'	100	80	25	133.5	52.2	26.3	44	12
'M'	126	98	36	226	91.6	55.3	63	14
'M'	117	102	32	243.6	127.8	48.2	60	11
'M'	128	102	34	274.3	113.4	61.4	81.8	14
'F'	96	77	27	107.2	37.9	28.4	34.6	13
'F'	123	97	32	231.5	100.1	49.9	63	14
'M'	113	87	30	198	115.9	36.5	41.2	9
'I'	88	62	23	72.5	26.8	16.4	24	11
'I'	100	75	28	111.8	47.5	27	33.8	12
'M'	148	107	37	330	146.8	90.1	67	14
'I'	102	80	25	111.5	52.3	23.9	30.5	11
'I'	86	63	19	75.6	35	16	20.9	10
'I'	105	81	25	131.4	59.7	30.1	33.6	11
'F'	113	90	29	169.9	84.3	33.7	45	12
'M'	72	54	18	44.5	16.6	10.6	15	9
'I'	74	57	19	45.2	22.7	10.3	13.5	9
'I'	55	39	18	22.5	10.9	5.9	7.1	8
'I'	93	74	23	106.8	52.2	19.6	28.6	10
'F'	114	89	29	175.5	82.4	43.4	44	12
'I'	130	104	30	247.6	109.9	59.2	66.1	14

```
'M'   152   115   38   365.8   140.7   77.2   112    17
'M'   114    91   31   166.4    71.7   34.8   55.4   13
'F'   130   107   35   257.9   121.9   55.3   68.8   13
'I'    33    22    4     3.8     1.3    0.5      1    6
'I'    84    62   20    56.1    22.5   12.3   18.5   10
'M'   125   101   43   289.1    99.2   57.4     87   17
'I'    67    50   19      37    15.9    9.9     11    9
'M'   127   102   34   271.1   123.8     61     78   13
'M'    69    51   18    40.1    18.8    5.9   12.6    9
'M'   125    94   34   233.3    92.1   51.3   78.9   15
'M'   133   101   32   257.8   122.9   50.6   73.3   13
'I'    32    22    5     3.9     1.5      1    1.2    6
'M'   140   110   39   324.9     135   69.4    107   16
'F'    88    68   27    79.5    30.1   18.9     27   12
'M'   119    95   32   263.5    81.6   46.8    116   17
'F'   107    83   37   168.3    62.8   31.7     60   14
'F'    81    65   22    71.1    30.2   12.6   23.4   10
'F'   142   109   35   381.4   174.5   91.3     95   14
'I'    64    47   18    36.6    19.6    6.7    8.4    8
'M'    75    57   19    50.6    19.2   11.5   18.5   10
'M'    90    66   21    99.1    51.5   16.4   25.8    9
'F'   132   105   40   292.6   130.5   59.9   84.4   14
'M'   130   104   35   253.1     123   55.5   67.2   13
'F'   113    91   30   164.1      73   31.8     52   13
'I'    84    65   25    78.3    31.5   20.5     23   11
'M'   124   105   31     217    90.8   39.3     70   14
'M'   133   107   31   276.6   119.2   51.3     97   14
'M'   130   103   25   236.1   104.7   56.6   65.5   13
'F'    86    67   24    88.8      31   22.9     28   12
'M'    98    93   25   104.5      47     26   28.2   12
'F'    93    70   23    84.2    31.3   18.2   26.9   12
'M'   100    80   25   134.5    67.2     24   36.5   10
'F'    76    61   21    56.2    20.9   12.3     18   10
'M'   144   112   36   317.3   138.2     75   88.5   15
'I'   118    93   39   217.7    73.7   37.4     75   15
'F'   135   107   32     282   118.4   63.5     84   15
'I'    90    67   19    70.1    32.3   12.5   23.7   10
'I'    85    65   20    79.6    23.7   12.9   18.9   11
'I'    77    60   20    57.9    24.3   12.6     18   10
'I'    51    39   11    14.5     5.7    3.4    4.2    8
'F'   131    91   34   257.9   117.4   63.3   68.3   13
'M'   103    76   27   132.3    57.5   41.9     31   12
'M'   112    83   26   152.3    73.9     34   39.1   11
'F'   127   101   37   260.7   100.2     59     82   16
'F'   110    87   34   176.8    57.5   32.9     56   15
'M'   134   104   38   327.7   162.3   73.8   78.2   12
'M'    85    61   22    71.8    34.6   17.5   19.5   10
'F'   136   101   34   268.7   131.4   59.4     71   13
'M'   119    91   31   208.2    83.2   42.1     73   14
'I'    91    73   27    88.2    30.3   23.3     29   12
'I'    88    68   24    99.9    59.3   18.9   23.7    9
'M'   115    95   29   171.4    73.3   34.6   53.8   13
'M'    92    70   24     103    44.8   21.6   31.3   11
'I'   103    81   26   114.6    42.6   26.8     39   13
'F'   110    82   29   165.7    61.9   38.1     50   13
```

```
*********************************************************************
```

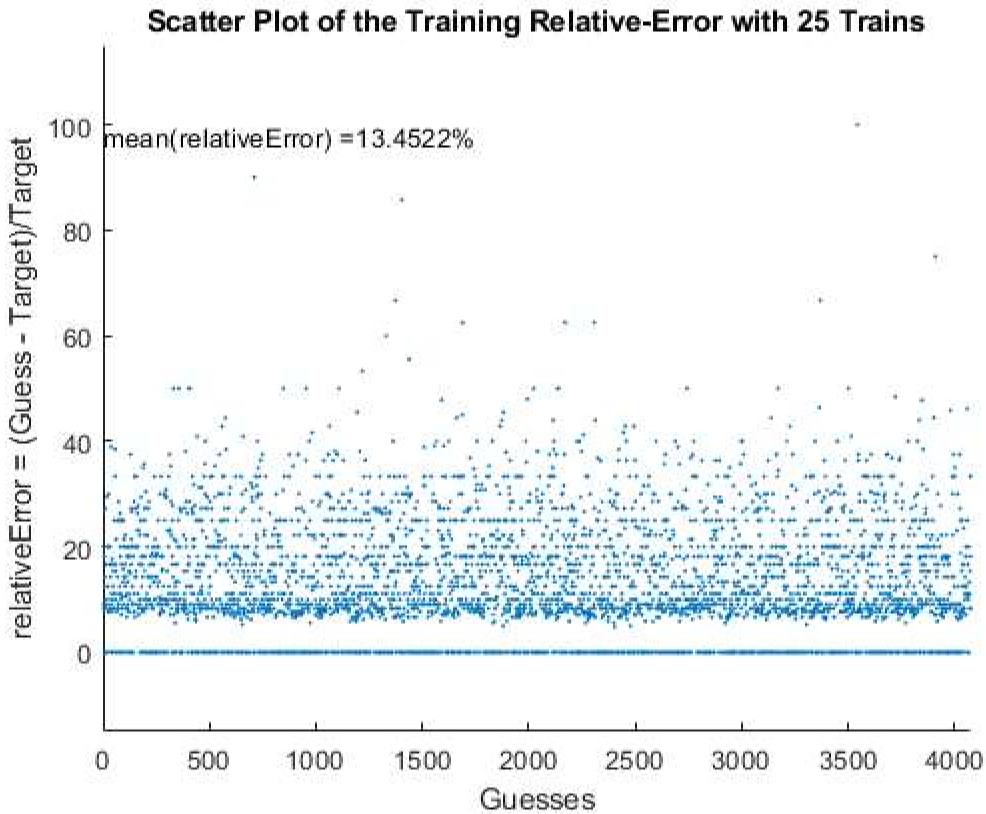
---

c) Give an estimate of the expected error of your neural network on new data. Explain your answer.

```
The espected relative error is around 13% (as calculated with
mean(error)). We expect a single neural network to get things right
every time, however that's not how the brain works. The firsst neural
network gets things wrong often. If we trained an artificial neural
```

```
network to reduce the error, we would need to slow the learning rate
early (learningRate = 0.00001), and halt long before over-fitting
(n = 25). However the 1st network would still get many answers wrong.
Then, we would need a second neural network, that receives the 1st
network mistakes to drop the error significantly.
```

```
% let's create more variables to see how well brain is trained
error = abs(guess - known)./known.*100; % error shall be close to zero ...
x = 1:length(error);
% scatter the points with blue filled dots
scatter(x,error,3,[0 0.4470 0.7410],'filled');
title("Scatter Plot of the Training Relative-Error with "+n+" Trains");
xlabel('Guesses');
xlim([0 length(error)]);
ylabel('relativeError = (Guess - Target)/Target');
ylim([-15 115]);
txt = strcat('mean(relativeError) = ', num2str(mean(error)), '%');
text(0,max(error)-2,txt) % print the error's mean into the chart
```



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