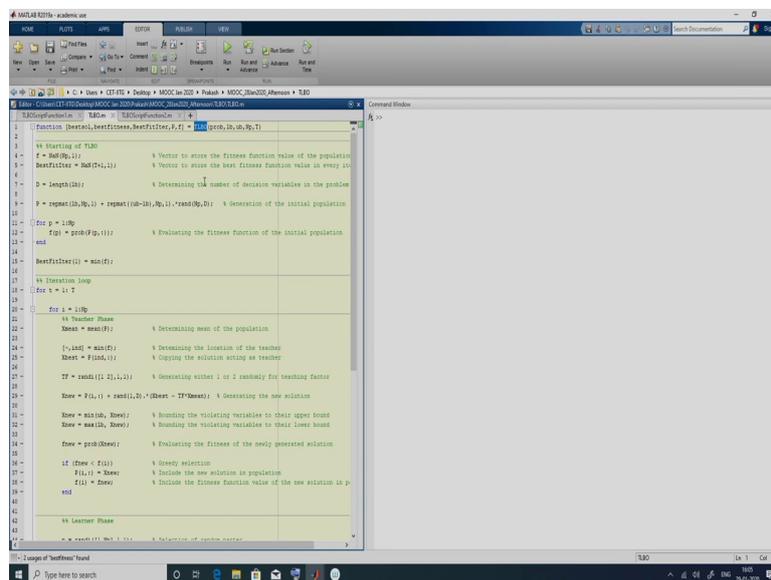


Computer Aided Applied Single Objective Optimization
Prof. Prakash Kotecha
Department of Chemical Engineering
Indian Institute of Technology, Guwahati

Lecture - 09
Implementation of TLBO in MATLAB

This is a supplementary session right. So, in this session we will see how to deploy multiple runs and do a statistical analysis right.

(Refer Slide Time: 00:38)

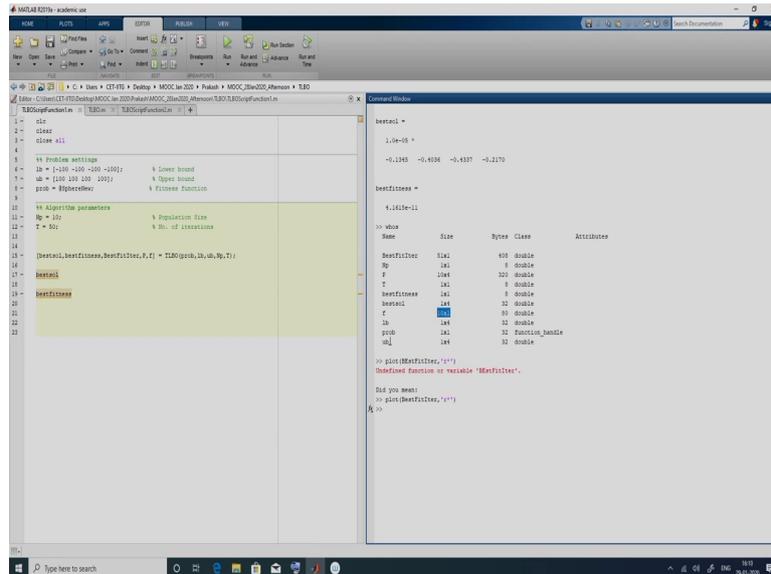


```
function [bestF, bestP] = TLBO(objFun, lb, ub, Np, TI)
% Starting of TLBO
f = objFun(lb); % Vector to store the fitness function value of the population
BestFitness = objFun(lb); % Vector to store the best fitness function value in every it
D = length(lb); % Determining the number of decision variables in the problem
P = repmat(lb, Np, 1) + repmat((ub-lb)/Np, 1, 1)*rand(Np, D); % Generation of the initial population
for p = 1:Np
    f(p) = objFun(P(p,:)); % Evaluating the fitness function of the initial population
end
BestFitness(i) = min(f);
% Iteration loop
for t = 1:TI
    % Teacher Phase
    Mean = mean(f); % Determining mean of the population
    [r, loc] = min(f); % Determining the location of the teacher
    Mean = P(loc,:); % Copying the solution acting as teacher
    TF = randi(1, 2, 1, 1); % Generating either 1 or 2 randomly for teaching factor
    New = P(i,:) + randi(1, 1, 1)*TF*(Mean - P(i,:)); % Generating the new solution
    New = min(lb, New); % Bounding the violating variables to their upper bound
    New = max(lb, New); % Bounding the violating variables to their lower bound
    New = objFun(New); % Evaluating the fitness of the newly generated solution
    if (New < f(i)) % Greedy selection
        f(i) = New; % Include the new solution in population
        P(i) = New; % Include the fitness function value of the new solution in p
    end
    % Learner Phase
    % = randi(1, 2, 1, 1); % Generation of random number
```

So, this TLBO function you might be remembering that we had made this TLBO function right. So right now it is a function file right. So, we need to only provide the detail of the problem right.

So, this has to be a function handle, the lower bounds of the problem, the upper bound, the number of population the population size and the number of iterations that we want to work with.

(Refer Slide Time: 01:01)



```
1 = c1c
2 = c1a2
3 = c1a2
4
5 %% Problem settings
6 lb = [-100 -100 -100 -100]; % Lower bound
7 ub = [100 100 100 100]; % Upper bound
8 prob = @sphere; % Fitness function
9
10 %% Algorithm parameters
11 Np = 10; % Population Size
12 T = 50; % No. of iterations
13
14 [bestval, bestfitness, bestFitter, f, F] = TLBO(prob, lb, ub, Np, T);
15
16 bestval
17
18 bestfitness
19
20 bestval
21
22 f
23
24 prob
25
26 obj
```

```
bestval =
    1.0e+05 *
    -0.1345    -0.4106    -0.4337    -0.2170

bestfitness =
    4.1417e+11

>> whos
Name      Size      Bytes  Class  Attributes
-----
bestFitter  1x1      408    double
Np         1x1      32     double
f          1x1      32     double
T          1x1      32     double
bestfitness 1x1      32     double
bestval    1x4      128    double
obj        1x1      32     double

>> plot(bestFitter, 'r')
Outdated function or variable 'bestFitter'.
Did you mean:
>> plot(bestfitness, 'r')
%>>
```

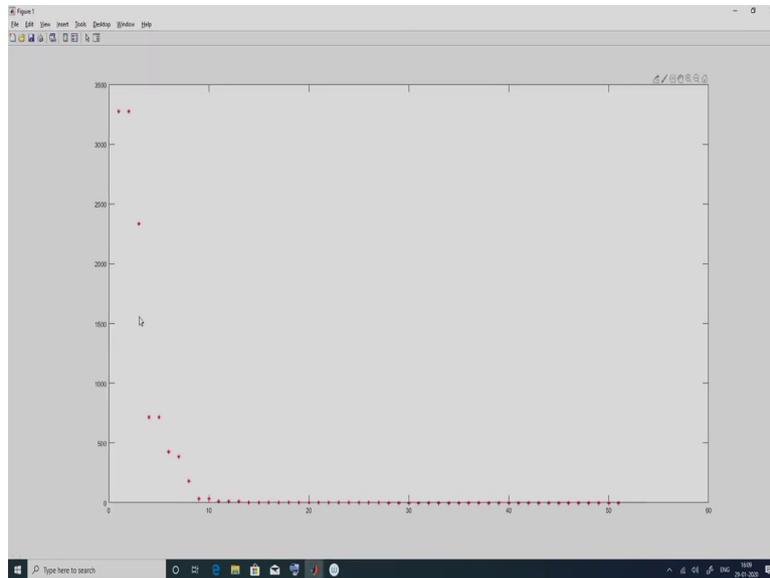
So, this is the script file, again this we have discussed right. So, here what we are doing is we are defining lb, ub problem right. So, let us just work with the sphere new function. So, we are setting the population size to be 10 and that the number of iterations to be 50, right. So, here we are calling the TLBO function and we are passing this details right and what we will be getting back is the best solution, the fitness corresponding to the best solution right, in each iteration what was the best fitness right, the final population right and the final fitness function value right.

So, remember this is different this BestFitIter is different from f, f is the fitness function value corresponding to each population member right. So, this is only of the last generation P comma f is of the last iteration whereas BestFitIter is the best fitness function value in every iteration; bestsolve again is the set of decision variable at the end of the algorithm the best solution that we have discovered right. So, this is decision variable and this is objective function right.

So, bestsolve if you see it will have in this case we have a 4 variable problem. So, it will be having 1 row 4 column, this will be a scalar 1 cross 1, we are having 50 iterations and remember we also have the initial evaluation of 50. So, this will be a vector of 51 rows and 1 column right we are working with the population size of 10. So, at the end of the iteration this will be 10 cross 4; P will be 10 cross 4 because we are working with the population size of 10 and the number of decision variable is 4 right. So, this will be 10 cross 4 and f will be a 10 cross 1 vector. Let me execute this right. So, if we execute this, let us do a whos. So, whos is going to show all the variables and their size right.

So, bestsolve it supposed to be a 1 cross 4 right. So, this is the best solution at the end of 50 iteration this is the best solution that TLBO has discovered this is the fitness function value corresponding to this solution right; BestFitIter if you see it is it has 51 rows and 1 column right. So, if we plot this, plot BestFitIter right. So, here I had used a upper case E right. So, that was the problem ok.

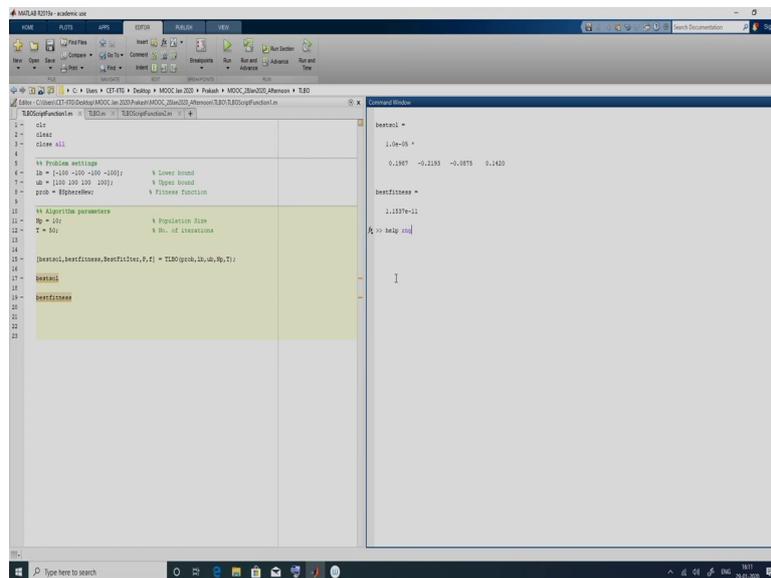
(Refer Slide Time: 03:41)



So, this is the convergence curve right, the x axis is iteration the y axis is the best functional value obtained at the end of that iteration. So, P if you see it will be a 10 cross 4 because 10 rows corresponding to each population member and 4 columns. Similarly f is 10 cross 1, 10 rows and 1 column, fitness function value for one solution is a scalar value.

So, we have 10 solutions over here. So, this will be 10 cross 1 right.

(Refer Slide Time: 04:13)



```
clear
clear all

% Problem settings
lb = [-100 -100 -100 -100]; % Lower bound
ub = [100 100 100 100]; % Upper bound
prob = @sphere; % Fitness function

% Algorithm parameters
Np = 10; % Population size
T = 50; % No. of iterations

[bestval,bestfitnes,bestfitter,F] = TSGA(prob,lb,ub,Np,T);

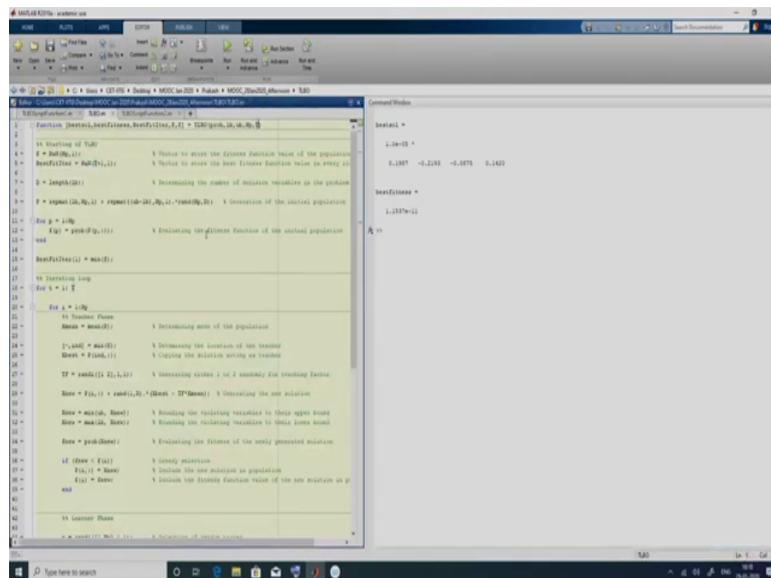
bestval
bestfitnes
```

```
bestval =
1.0e+00 *
0.1897 -0.2183 -0.1875 0.1420

bestfitnes =
1.1337e+11
% >> help tsga
```

So, now, if you if you execute this, so, now we have a value of fitness function is 7.95, right. So, if you again execute this I get a different fitness function value 4.10, 4.56, 2.2, 1.24, 1.15..

(Refer Slide Time: 04:35).



```
function [bestfit, bestfitval, bestfitind, bestfitval, bestfitind] = GA(popsize, numvars, fitnessfcn, numelit, numgen, numcrossover, nummutation, numelit, numgen, numcrossover, nummutation)
% GA: Genetic Algorithm
% Syntax: [bestfit, bestfitval, bestfitind, bestfitval, bestfitind] = GA(popsize, numvars, fitnessfcn, numelit, numgen, numcrossover, nummutation)
% popsize: Initial population size
% numvars: Number of variables
% fitnessfcn: Fitness function handle
% numelit: Number of elite individuals
% numgen: Number of generations
% numcrossover: Crossover probability
% nummutation: Mutation probability

% Initialization
bestfit = zeros(1, numvars);
bestfitval = inf;
bestfitind = 0;

% Main loop
for gen = 1:numgen
    % Create initial population
    pop = randi(10, popsize, numvars);

    % Evaluate fitness
    fitval = fitnessfcn(pop);

    % Sort by fitness
    [bestfitval, bestfitind] = sort(fitval, 'ascend');

    % Elitism
    bestfit = pop(bestfitind, :);
    bestfitval = fitval(bestfitind);

    % Crossover
    [pop, fitval] = crossover(pop, fitval, numcrossover);

    % Mutation
    [pop, fitval] = mutate(pop, fitval, nummutation);

    % Selection
    [bestfitval, bestfitind] = sort(fitval, 'ascend');
    bestfit = pop(bestfitind, :);
    bestfitval = fitval(bestfitind);

    % Display progress
    fprintf('Gen %d: Best fitness = %f\n', gen, bestfitval);
end

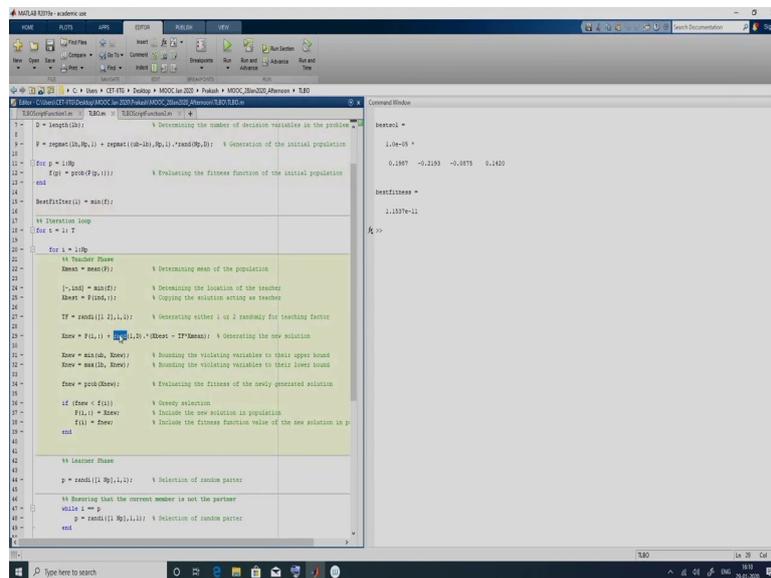
% Final results
bestfitval = bestfitval;
bestfitind = bestfitind;
bestfit = bestfit;
end
```

Command Window

```
bestfit =  
1.1e-05  
0.187 -0.2189 -0.1875 0.1421  
bestfitval =  
1.137e+11  
>>
```

So, this is happening because the algorithm is stochastic, remember this algorithm the very starting we are saying that randomly initialize a population right.

(Refer Slide Time: 04:46).



```
1 p = length(x); % Determining the number of decision variables in the problem
2
3 f = repmat(10,lp,1) + repmat(-10,-lp,1) * rand(lp,1); % Generation of the initial population
4
5 for p = 1:lp
6     f(p) = rand(f(p),1); % Evaluating the fitness function of the initial population
7 end
8
9 BestFitness() = min(f);
10
11 %% Iteration loop
12 for t = 1:T
13
14     for i = 1:lp
15         %% Teacher Phase
16         Mean = mean(f); % Determining mean of the population
17
18         [i, best] = min(f); % Determining the location of the teacher
19         Best = f(best,i); % Copying the solution acting as teacher
20
21         TF = randi([1,2],1,1); % Generating either 1 or 2 randomly for teaching factor
22
23         New = f(i,i) + TF * (1,0) * (Best - f(i,mean)); % Generating the new solution
24
25         New = min(max(New, -10), 10); % Bounding the resulting variables to their upper bound
26         New = max(min(New, -10), -10); % Bounding the resulting variables to their lower bound
27
28         New = rand(New); % Evaluating the fitness of the newly generated solution
29
30         if (New < f(i)) % Greedy selection
31             f(i,i) = New; % Include the new solution in population
32             f(i) = New; % Include the fitness function value of the new solution in p
33         end
34
35         %% Learner Phase
36
37         p = randi([1,lp],1,1); % Selection of random partner
38
39         %% Ensuring that the current member is not the partner
40         while i == p
41             p = randi([1,lp],1,1); % Selection of random partner
42         end
43
44     end
45 end
```

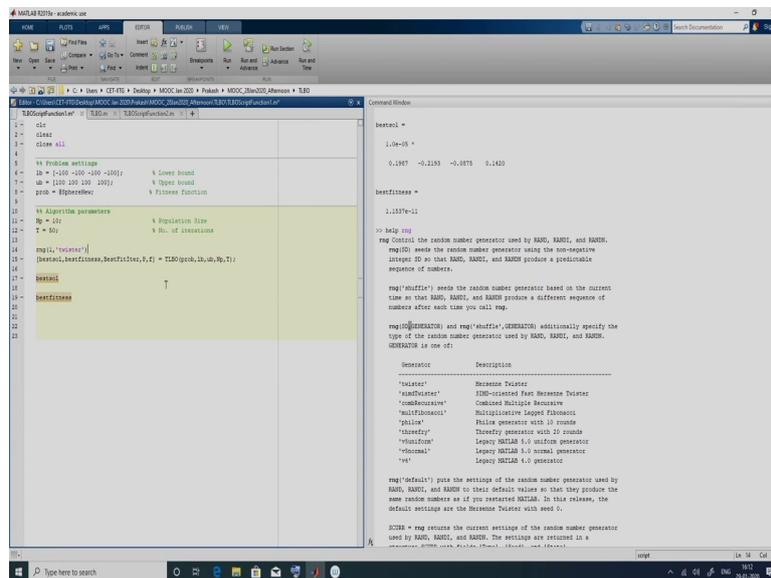
bestval =
1.0e+08 *
0.1987 -0.2189 -0.1875 0.1420

bestfitness =
1.1376e+11

So, every time we run it is going to randomly initialize the population right and in multiple places we are using this random selection right. Here again we are using generating random numbers, here we are randomly choosing the TF to be 1 or 2. So, every time we executed we are going to get a different solution..

So, in this case the question is how do we reproduce the results right. So, what we can do is we can make use of this function rng in MATLAB right help rng right to.

(Refer Slide Time: 05:11)



```
clear
clear all

% Problem settings
lb = [-100 -100 -100 -100]; % Lower bound
ub = [100 100 100 100]; % Upper bound
prob = @sphereval; % Fitness function

% Algorithm parameters
Ng = 10; % Population size
T = 50; % No. of iterations
rng('twister');
[bestcost,bestfittest,bestfitter,T] = TGA(prob,lb,ub,Ng,T);

bestcost
bestfittest
```

```
bestcost =
    1.0e+08 *
    0.1897 -0.2183 -0.1875  0.1420

bestfittest =
    1.137e+11

>> help rng
rng Control the random number generator used by RAND, RANDI, and RANDJ.
rng(SD) resets the random number generator using the non-negative
integer SD so that RAND, RANDI, and RANDJ produce a predictable
sequence of numbers.

rng('shuffle') resets the random number generator based on the current
time so that RAND, RANDI, and RANDJ produce a different sequence of
numbers after each time you call rng.

rng(SD,GENERATOR) and rng('shuffle',GENERATOR) additionally specify the
type of the random number generator used by RAND, RANDI, and RANDJ.
GENERATOR is one of:

Generator      Description
-----
'twister'      Standard Twister
'randRNG'      SIMD-optimized Fast Inverse Expatriate
'combRNG'      Combined Multiple Recursive
'xorshift1024' Multidimensional Layered Permuted
'philox'       Philox generator with 10 rounds
'isdrng'       Isdrng generator with 20 rounds
'isdrng64'     Isdrng64 generator
'isdrng128'    Isdrng128 generator
'isdrng256'    Isdrng256 generator
'isdrng512'    Isdrng512 generator

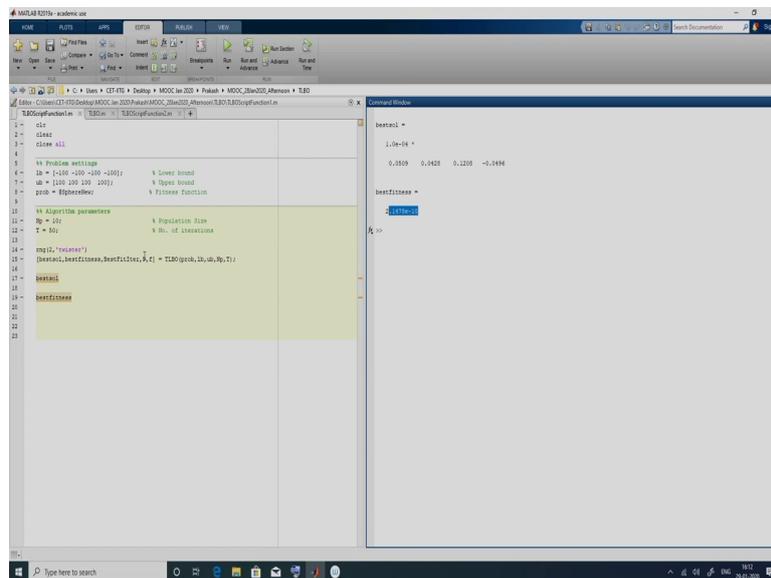
rng('default') puts the settings of the random number generator used by
RAND, RANDI, and RANDJ to their default values so that they produce the
same random numbers as if you restarted MATLAB. In this release, the
default settings use the Inverse Expatriate with seed 0.

DCEM = rng resets the current settings of the random number generator
used by RAND, RANDI, and RANDJ. The settings are returned in a
structure with the following fields:
```

So, it will help us to control the random number generate, that is generated right. So, what the syntax of rng that we will be using is rng SD comma GENERATOR right. So, generator can be any of this 9 values right. So, they have 9 different algorithms to generate random numbers, the MATLAB generate pseudo random number right using one of these algorithms right and SD is a integer value right..

So, if we have over here rng 1 comma let us say twister right and if we save this and if we execute it right, every time we will get the same set same solution right because every time before executing this function we are resetting the random number generator right.

(Refer Slide Time: 05:51)



```
clear
clear all

% Problem settings
lb = [-100 -100 -100 -100]; % Lower bound
ub = [100 100 100 100]; % Upper bound
prob = @sphere; % Fitness function

% Algorithm parameters
Np = 10; % Population size
T = 50; % No. of iterations

rng('twister')
[bestval,bestfitmax,bestfitter,B,F] = TGA(prob,lb,ub,Np,T);

bestval
bestfitmax
```

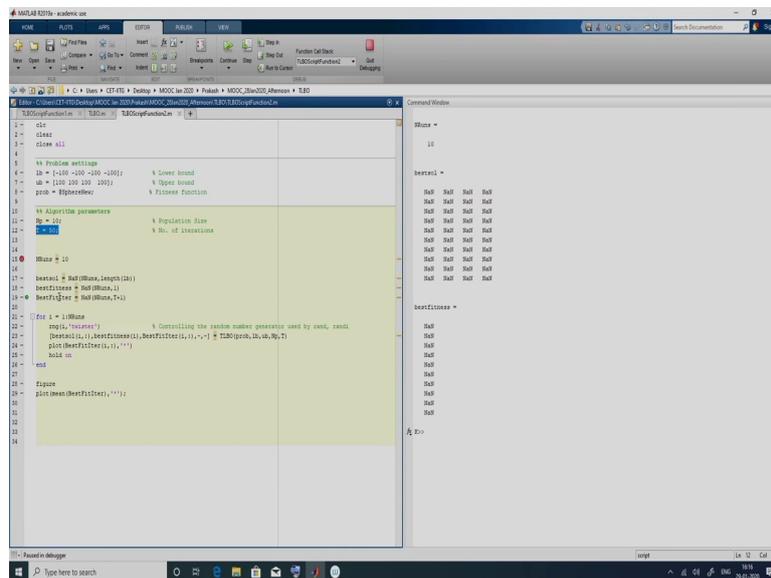
Command Window

```
bestval =
1.0e-04 *
0.2809 0.2420 0.2200 -0.2494

bestfitmax =
-2.471e+01
```

So, in this way we will be able to reproduce the results right. So, now, the question is if you are able to reproduce the results why should I have it as just 1 why not 2 right. So, if I change that the value would change right. So, now, we have the fitness function to be 2.47 into 10 power minus 10 right. So, since this algorithms are stochastic we are supposed to run it multiple times right.

(Refer Slide Time: 06:33)



```
1 clear
2 close
3 close all
4
5 % Problem settings
6 lb = [-100 -100 -100 -100]; % Lower bound
7 ub = [100 100 100 100]; % Upper bound
8 prob = @SphereEval; % Fitness function
9
10 % Algorithm parameters
11 pop_size = 10; % Population size
12 iter_max = 100; % No. of iterations
13
14 NRuns = 10;
15
16 bestsol = NaN(NRuns,length(lb));
17 bestfitness = NaN(NRuns,1);
18 bestfitvec = NaN(NRuns,4);
19
20 for i = 1:NRuns
21     rng(i,'shuffle'); % Controlling the random number generator used by rand, randi
22     [bestsol(i),bestfitness(i),bestfitvec(i,:),~] = TSO(pop_size,ub,lb,prob);
23     plot(bestfitvec(i,:),');
24 end
25
26 class
27 plot(handles.bestfitvec,'');
28
29
30
31
32
33
34
```

```
bestsol =
NaN NaN NaN NaN

bestfitness =
NaN
```

So, we run multiple times and then we do a statistical analysis right. In this function we are going to implement the multiple runs right. So, over here we have define the number of runs to be 10 right.

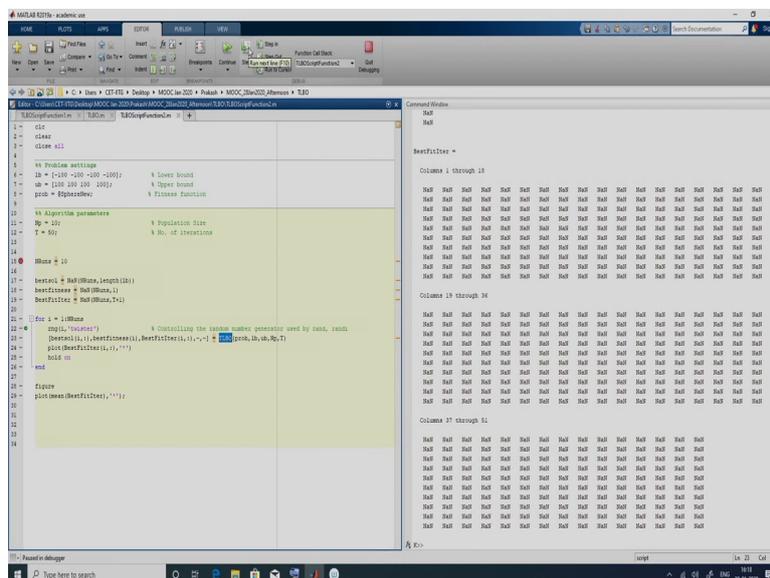
So, then we will define some of the variables which we will be using right. So, the first variable that we would require is bestsol. So, every time we run it. We will get a 1 row and as many columns as the number of decision variables right. So, we are defining bestsol with Na with the values of NaN right and that matrix will have 10 rows or the number of runs NRuns comma 4 columns in this case right because we have a 4 variable problem right..

So, this length of lb will give us 4 and this NRuns is 10 right. So, this is just initialization. So, every time we run this problem we will store the best solution over here right and we will

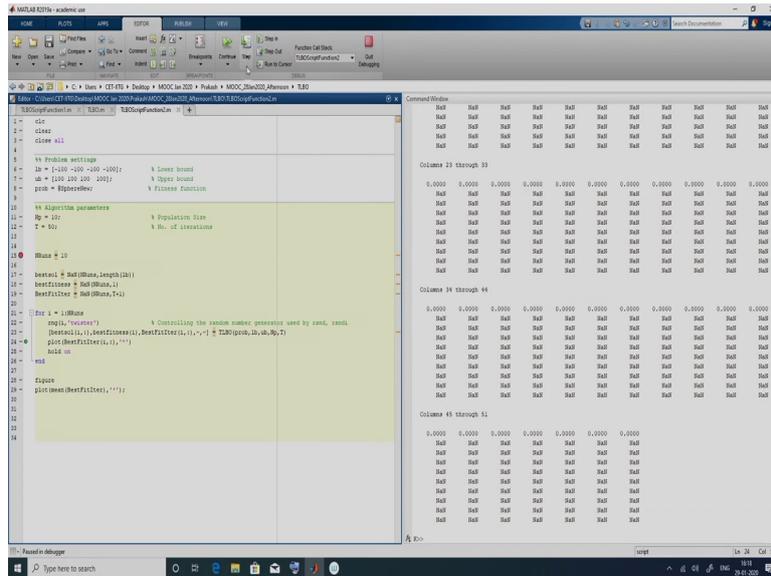
save the fitness function in best fitness right. So, best fitness if you remember it was a scalar value it is a scalar value for 1 run. So, for 10 runs it is going to be a column vector right.

So, we have 10 rows and 1 column, for every run we will get 51 column because there are 50 iteration and the first initial population will also have the best fitness function value right. So, this will be 51. So, that is why we are doing T plus 1; number of iterations plus 1 and for every run we will have a convergence curve right. So, that is why we have this BestFitIter right.

(Refer Slide Time: 07:56)

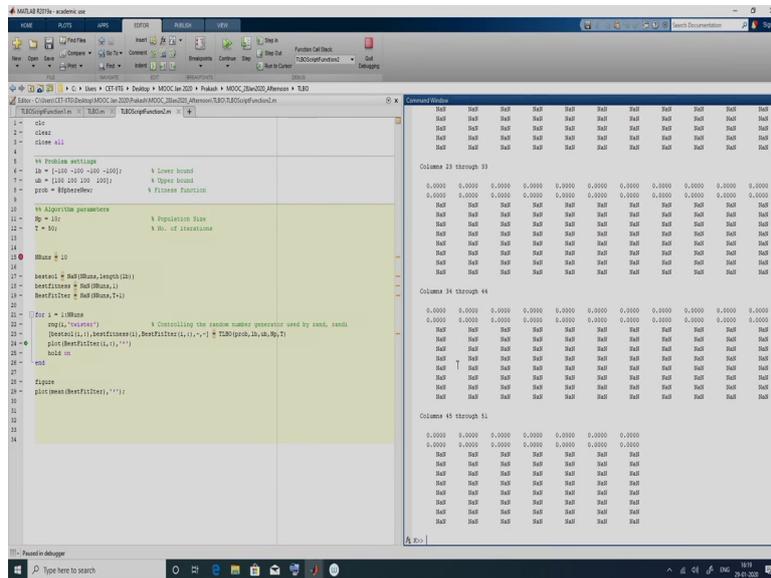


So, BestFitIter if you see now we have 51 columns and the number of rows would be 10 right. So, if you do whos over here.



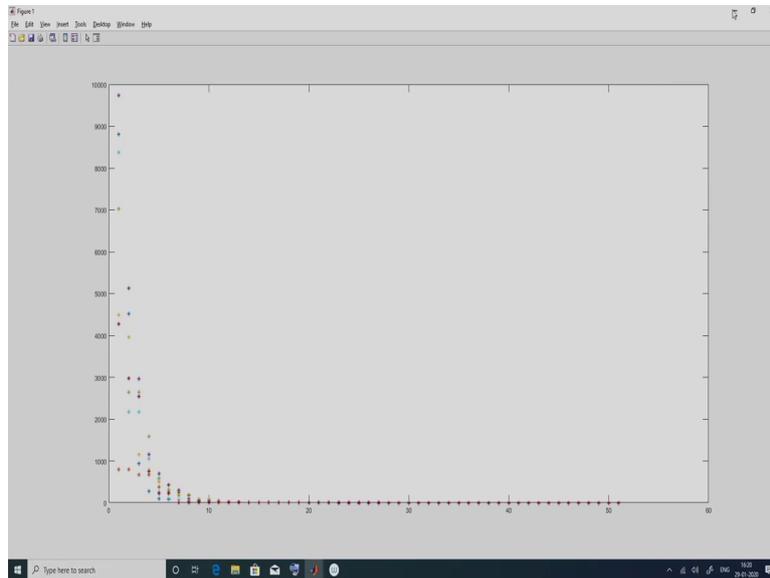
So, it has completed the first run. So, after completion of the first run if you see the best solution the first row has been populated.

(Refer Slide Time: 09:46)



So, this has 51 columns right. So, then we are plotting it right.

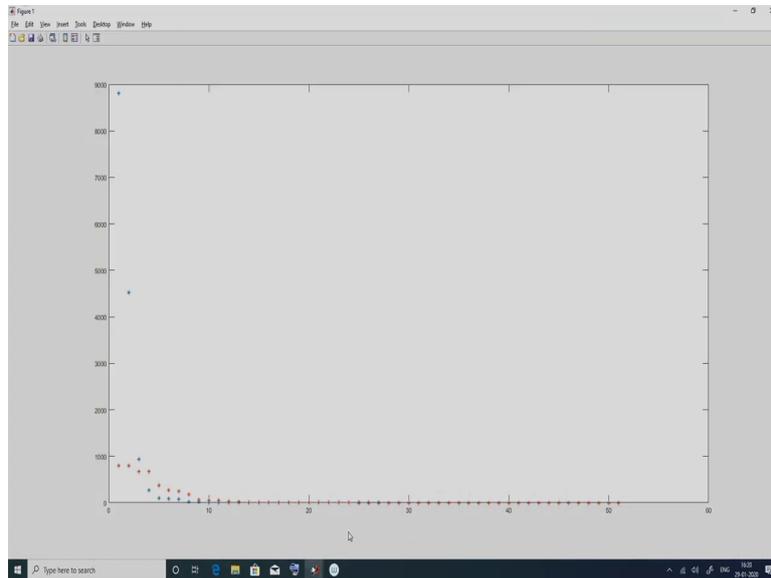
(Refer Slide Time: 09:52)



So, Step. So, this is the plot of the first run right. So, the x axis is again iteration, the y axis is the best fitness function value and this shows the convergence of the first run right. So, similarly we can proceed for the second run right. So, the second run we want to plot on the same plot that is why we have hold on right. I want the values of the first one to remain and I want to plot the values of the second run right. So, if we do this Step. So, now, it is i is equal to 2 right.

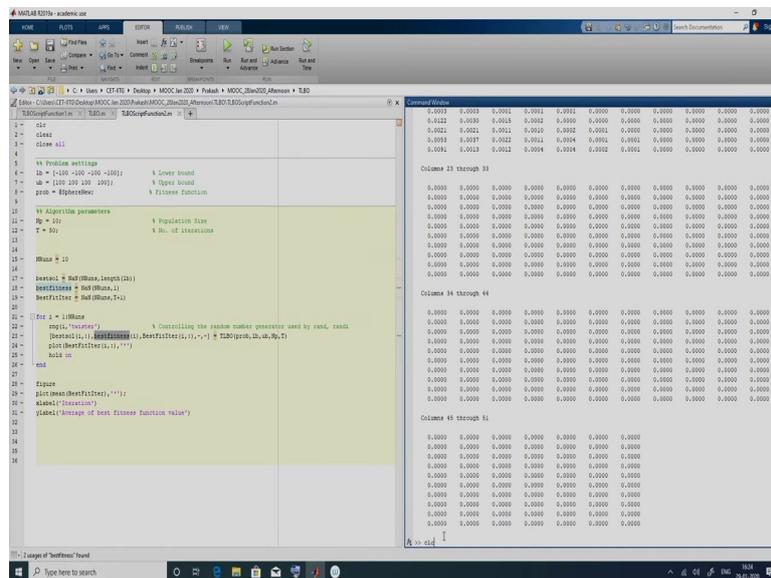
So, when we when this line is executed 22 second line is executed it will reset the random number generator with a seed of 2 right. So, again if you do Step right.

(Refer Slide Time: 00:00).



So, now, we will see we will have 2 colours right. So, previously we had this blue colour right. So, now, we have another curve over here right.

(Refer Slide Time: 11:13)



So, this now we can execute for 10 times right. So, every time row would get populated right and the figure will also have one more curve. So, as you see for every run we get a curve over here right. So, right now we have completed 8 runs, we are in the eighth run right. So, it has completed all the 10 runs right. So, at the end of 10 runs this is what we have.

(Refer Slide Time: 11:50)

```
clear
clear all
% Problem settings
lb = [-100 -100 -100 -100]; % Lower bound
ub = [100 100 100 100]; % Upper bound
prob = @sphere; % Fitness function
% Algorithm parameters
Np = 10; % Population size
T = 50; % No. of iterations
% Run 10 times
for i = 1:10
    [bestval, bestfitnes] = BestFitIter(
        prob, lb, ub, Np, T);
    fprintf('Run %d: Best fitness = %f, Best value = %f\n', i, bestfitnes, bestval);
end
class
plot(bestfitnes, 'r');
title('Best fitness vs Run');
xlabel('Run');
ylabel('Best fitness');

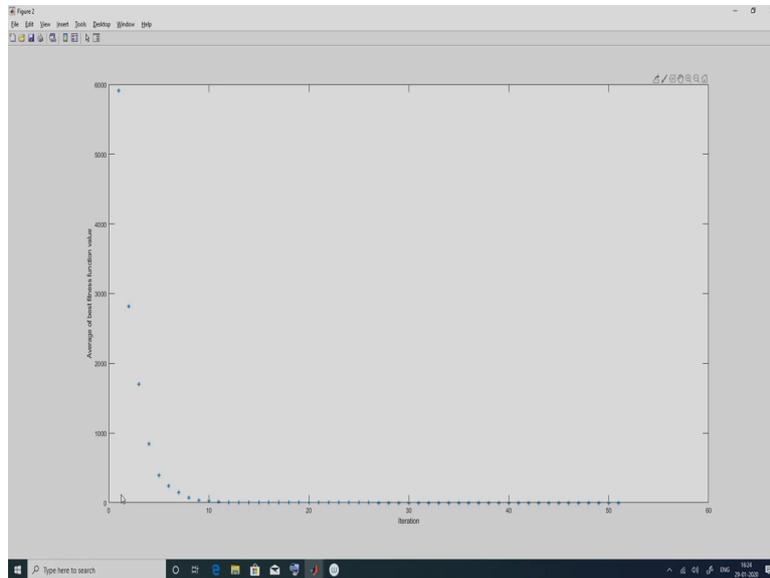
```

Command Window

```
E> bestval
bestval =
1.1e-04
-1.0148 -0.0000 -0.0000 -0.0033
0.0559 0.0428 0.1208 -0.0486
-0.0184 -0.0178 -0.0214 0.0029
-0.0245 -0.0121 -0.0280 0.0087
-0.0020 0.0055 0.0011 0.0016
-0.0013 0.0050 0.0009 -0.0026
0.0033 0.0001 0.0164 0.0143
0.0090 -0.0180 -0.0018 -0.0493
0.0004 -0.0030 0.0111 0.0030
0.0180 0.1997 0.1472 -0.2142
E> bestfitnes
bestfitnes =
1.1e-04
0.0003
0.0011
0.0011
0.0009
0.0000
0.0001
0.0001
0.0022
0.0002
0.1078
>> bestfitnes(i,1)
Undefined function or variable 'bestfitnes'.
Did you mean:
A >> bestfitnes(i,1)
```

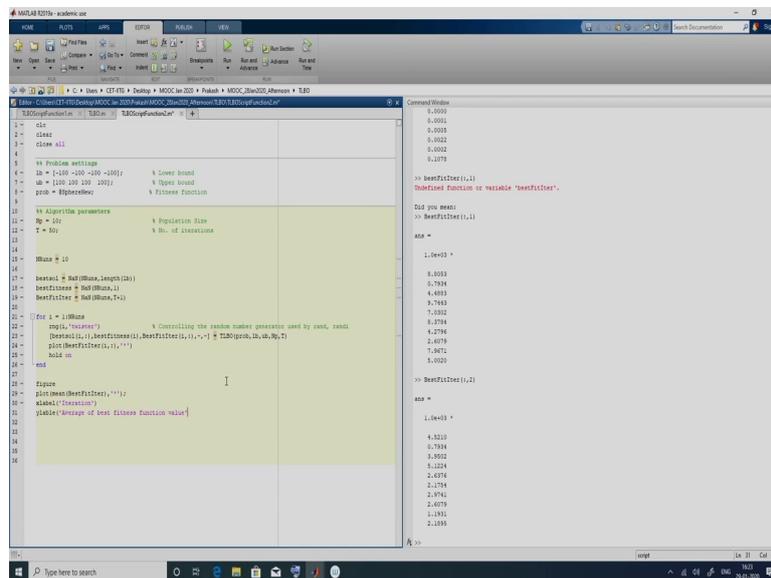
If we see the best solution right and the best fitness, so, for every time the fitness function value that was obtained at the end of 50 iterations is given over here right. So, this is the result of the 10 runs right. So, now, what we can do is if you look into this BestFitIter the rows indicate the run, the column indicates the fitness function value. So, we can find out the mean right. So, we will get.

(Refer Slide Time: 12:26)



So, we can plot the mean over right. So, this is the mean. So, remember we had 51 convergence curves right. So, at the end of first iteration right the average of all the 10 runs. So, for example, let us say best Fit Iter right. So, I am looking for the all the runs the first column right.

(Refer Slide Time: 12:59)



```
clear
close all

% Problem settings
lb = [-100 -100 -100]; % Lower bound
ub = [100 100 100]; % Upper bound
prob = HyperSphere; % Fitness function

% Algorithm parameters
Np = 10; % Population size
T = 50; % No. of iterations
Mmax = 10;

bestval = Inf; % Initial best value
bestfit = NaN; % Initial best fitness
bestfitvec = NaN; % Initial best fitness vector

for i = 1:Mmax
    rng('shuffle'); % Controlling the random number generator used by rand, randi
    [bestval(i), bestfitvec(i), bestfit(i), ~] = TSB(popub, lb, ub, Np, T);
    hold on
end

figure
plot(bestfitvec, 'r');
xlabel('Iteration');
ylabel('Average of best fitness function value');
```

```
>> bestfitvec(1:1)
ans =
    1.1e+03
    0.9593
    0.7894
    4.4833
    5.7883
    5.0302
    0.3794
    2.0779
    5.0672
    5.0020

>> bestfitvec(1:2)
ans =
    1.1e+03
    4.3210
    5.7884
    5.9502
    5.1224
    2.0776
    2.1754
    2.0792
    2.0779
    1.1951
    2.1189
```

So, the first column the first column will correspond to the zeroth iteration right and the second column will correspond to the first iteration at the end of first iteration. So, at the end of first iteration this is what we had the mean of that column is this particular point right. So, at the end of first iteration what is the average fitness function value obtained across all the 10 runs right.

So, this is again best fitness function value average of the 10 runs, the y axis is average of the 10 runs where as the x axis is iteration right. So, this is how we can we can have a single convergence curve which reflects all the 10 runs that we have executed. So, we can add the x label and y label. So, x label is Iteration and y label is right. So, Average of best fitness function value. So, this is the iteration and this is average of the best fitness function value at

(Refer Slide Time: 14:28)

The image shows a MATLAB Editor window with a script and its output. The script defines a fitness function and runs a genetic algorithm 10 times. The output window displays the best fitness values for each run.

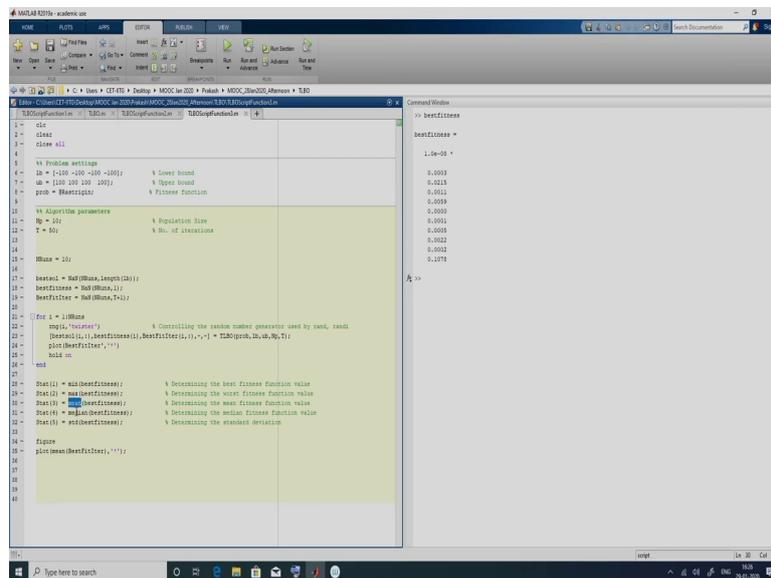
```
1 clear
2 close
3 close all
4
5 % Problem settings
6 lb = [100 100 100 100]; % Lower bound
7 ub = [100 100 100 100]; % Upper bound
8 prob = @sphere; % Fitness function
9
10 % Algorithm parameters
11 Np = 10; % Population size
12 T = 50; % No. of iterations
13
14
15 NRuns = 10
16
17 bestval = NaN(NRuns,length(lb))
18 bestfitness = NaN(NRuns,1)
19 bestfitvec = NaN(NRuns,7)
20
21 for i = 1:NRuns
22     rng(i,'twister') % Controlling the random number generator used by rand, randi
23     [bestval(i,:),bestfitness(i),bestfitvec(i,:),T] = ga(prob,lb,ub,Np,T)
24     hold on
25 end
26
27
28 plot(bestval,'o');
29 xlabel('Iteration')
30 ylabel('Average of best fitness function value')
31
32
33
34
```

Output window shows:

```
>> bestfitness
bestfitness =
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
```

So, this bestfitness has 10 values. So, now, we have this bestfitness function value right. So, now, we can perform a statistical analysis of this right as to what was the best value we obtain in the 10 runs? What is the worst value we obtained in the 10 runs? What is the mean of the 10 runs? What is the standard deviation among the 10 runs?

(Refer Slide Time: 14:53)



```
clear
clear all

% Problem settings
lb = [-100 -100 -100]; % Lower bound
ub = [100 100 100]; % Upper bound
prob = Wierzbinski; % Fitness function

% Algorithm parameters
Np = 10; % Population size
T = 50; % No. of iterations
Mmax = 10;

bestval = Inf; % Initial best fitness value
bestfitvec = NaN(Mmax,1); % Initial best fitness vector
bestfitvar = NaN(Mmax,1); % Initial best fitness variance

for i = 1:Mmax
    rng(i,'twister') % Controlling the random number generator used by rand, randi
    [bestval(i),bestfitvec(i),bestfitvar(i),...] = TGA(prob,lb,ub,Np,T);
end

Stat(i) = min(bestfitvec); % Determining the best fitness function value
Stat(i) = max(bestfitvec); % Determining the worst fitness function value
Stat(i) = sum(bestfitvec); % Determining the mean fitness function value
Stat(i) = std(bestfitvec); % Determining the median fitness function value

figure
plot(bestfitvec);
```

Command Window

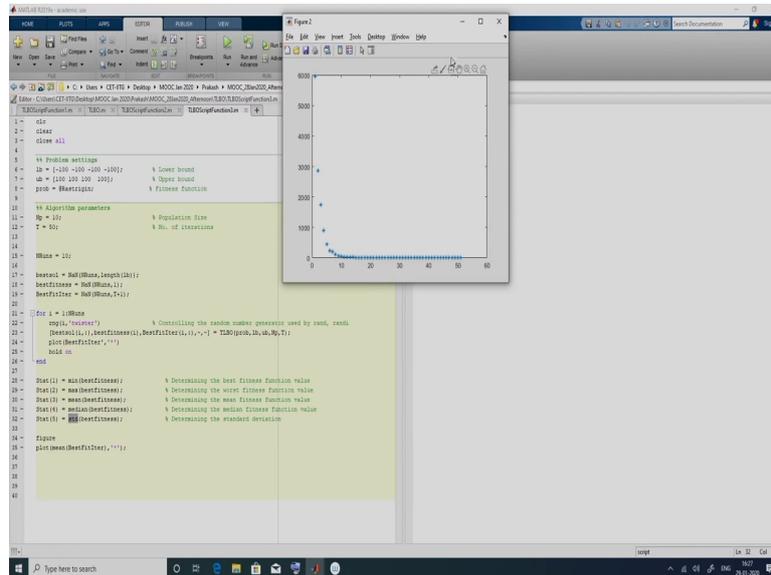
```
>> bestfitvec
bestfitvec =
1.1e-03
0.0003
0.0015
0.0011
0.0009
0.0009
0.0005
0.0005
0.0002
0.0002
0.1079
```

So, that is what is done in this file right. So, here if you see we have discussed all these 3 rights. So, similarly whatever we have discussed previously all this we have discussed previously. So, we are defining a variable called as Stat right it is going to have 5 values right the first value is going to be the best of the fitness. So, we have this 10 runs right what is the best among; What is the best among this run? right. So, that is what will be bestfitness right the worst is the maximum value. So, max of bestfitness is going to be the second column right, mean of the bestfitness is going to be the third column of Stat, a median of bestfitness is going to be the fourth column of the variable Stat and the fifth column of the variable Stat is going to be the standard deviation.

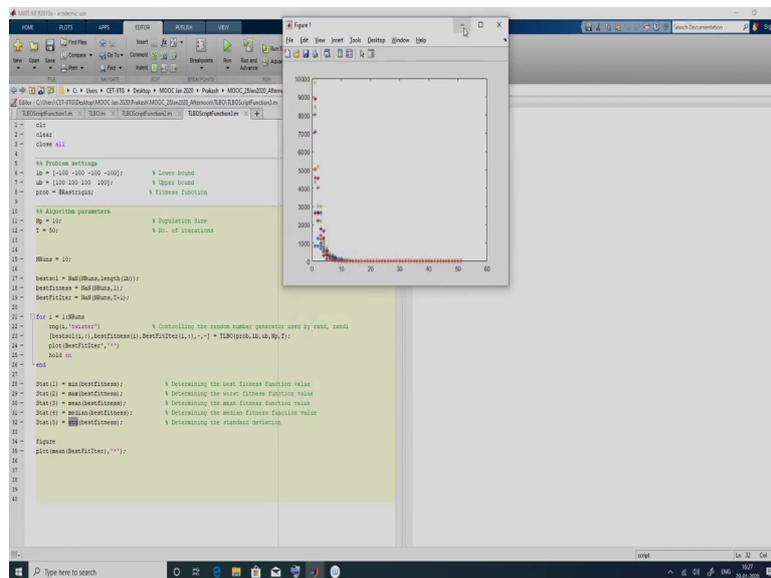
So, we have assigned that the first value is minimum the or the best, the second value is the maximum among the 10 runs or the worst mean, median and standard deviation right. So, all this 5 are in built functions right. So, to find out the minimum value maximum value the

mean value the median value and the standard deviation right. So, if we now execute this right.

(Refer Slide Time: 16:06)



(Refer Slide Time: 16:08)



So, this is the mean fitness curve which you know this is a convergence curve of each run right. So, here if we say Stat right.

(Refer Slide Time: 16:15)

```
clear
clear all

% Problem settings
lb = [-100 -100 -100]; % Lower bound
ub = [100 100 100]; % Upper bound
prob = @rastrigin; % Fitness function

% Algorithm parameters
Np = 10; % Population size
T = 50; % No. of iterations

Mmax = 10;

bestval = Inf; % Initializing the best fitness function value
bestfitvec = NaN(1,3); % Initializing the best fitness function value
bestfitvec = NaN(1,3); % Initializing the best fitness function value

for i = 1:Mmax
    rng('shuffle'); % Controlling the random number generator used by rand, randi
    [bestval(i), bestfitvec(i), bestfitvec(i), bestfitvec(i)] = TBO(prob,lb,ub,Np,T);
    hold on
end

[bestval] = min(bestfitvec); % Determining the best fitness function value
[bestfitvec] = bestfitvec; % Determining the best fitness function value
[bestfitvec] = bestfitvec; % Determining the best fitness function value
[bestfitvec] = bestfitvec; % Determining the best fitness function value

bestval(ind,:);

figure
plot(bestfitvec,'r');
axis([0 100 0 100]);
```

```
>> Stat =
    Stat =
    1.3916    5.7834    3.5686    3.1093    1.4969

>> bestfitvec =
    bestfitvec =
    2.7934
    2.6094
    3.1042
    3.0836
    3.0888
    2.1345
    3.2665
    3.1123
    3.0429
    3.9721
```

So, the 10 times we run this problem the Rastrigin function problem right the best that we could get was 1.3916 the worst that we got was in the 10 runs 5.7834 right the average of the 10 runs is 3.5686 the median of the 10 runs is 3.0193 and the and the standard deviation is 1.4969 right. So, this is nothing, but the statistical analysis of this vector bestfitness right. So, here if we see the best value is 1.396 the worst value is the first run 5.7834 the mean if you calculate the mean of this it will work out to be 3.5687 the median is 3.1093 and the standard deviation is 1.496. So, if we are interested in the decision variable corresponding to this 1.3916 let us say we are interested what is what is a set of decision variable that will give us this 1.3916. So, over here we can modify this as in addition to the value we can also get the location right.

So, ind will be the location. So, in this case it will return 3 4 5 because its located in the fifth one and best solution we have saved in over here bestsolve right. So, bestsolve right. So, we are interested in the this row and all the columns right.

(Refer Slide Time: 17:51)

```

1 = c1d
2 = c1daz
3 = c1daz all
4
5 %% Problem settings
6 lb = [-100 -100 -100 -100]; % Lower bound
7 ub = [100 100 100 100]; % Upper bound
8 pobj = BestFitness % Fitness function
9
10 %% Algorithmic parameters
11 Np = 10; % Population Size
12 T = 50; % No. of iterations
13
14 Wmax = 10;
15 bestsol = NaN(Inf, length(lb));
16 bestfitness = NaN(Inf, 1);
17 bestfititer = NaN(Inf, 1);
18
19 for i = 1:Nmax
20     rng('shuffle'); % Initializing the random number generator used by rand, randi
21     [bestfit(i), bestfitness(i), bestfititer(i), ~] = TGA(pobj, lb, ub, Np, T);
22     plot(bestfit, 'r');
23     hold on
24 end
25
26 [bestsol(ind), ~] % Determining the best fitness function value
27
28 Stat(1) = min(bestfitness); % Determining the worst fitness function value
29 Stat(2) = max(bestfitness); % Determining the best fitness function value
30 Stat(3) = median(bestfitness); % Determining the median fitness function value
31 Stat(4) = std(bestfitness); % Determining the standard deviation
32
33 bestsol(ind, :)
34
35 figure
36 plot(bestfit, 'r');
37
38
39
40
41
42

```

```

ans =
0.9727 -0.0130 0.0083 -0.0086
>> Stat
Stat =
1.3916 1.7034 3.5464 3.1093 1.4949
>> bestfitness
bestfitness =
1.7034
2.4094
3.1042
0.6559
1.3916
2.1245
0.2445
3.1123
0.6559
1.9721
>> bestsol
bestsol =
0.0547 -1.0246 -1.0774 -0.9307
-0.0317 -0.0377 -1.0015 -0.9466
-0.0813 -0.0307 1.0093 0.0877
-0.0095 -0.0041 -0.0023 0.9029
0.9727 -0.0130 0.0083 -0.0086
-0.0467 -0.0434 -0.0749 -0.0304
-1.0337 -0.0875 0.9451 -1.0007
-1.0049 0.0042 -0.9269 -0.0390
-0.0773 -0.0023 -0.0054 -0.0045
1.9721 0.0463 -0.0045 -0.9464

```

So, this will give us the best solution right. So, this is the Stat right. So, the bestfitness function value is 1.3916 right. So, if we see bestfitness it is 1.3916 and the corresponding solution is this one or we can look at bestsol.

So, bestsol remember it will be a 10 cross 4 matrix right. So, the fourth the fifth one right. So, the fifth one is 1 2 3 4 fifth one is this one. So, which is what was given over here. So, that is how we extracted the best solution.

So, this is how we can perform statistical analysis we take an algorithm right run it multiple times on the same problem and then we find out among the number of runs which we have executed. What is the best value? What is the worst value? What is the mean standard deviation and median? That is the end of this session.