**Main solution steps:**

* Fitness standard taking the chromosome and calculate the real number by equation: x = x(min) + ((sum from j =0 to L -1” the length of gene” \*2L-j-1 )/2L)\*x(max)-x(min) by creating nested loop to calculate this.
* Fitness gray also taking the chromosome and calculate the real number different equation: x = x(min) + (((sum from j =0 to L -1” the length of gene” (sum (from k=0 to j) %2) \*2L-j-1)/2L)\*x(max)-x(min) this equation to solve the hamming cliff.
* We have two fitness standard and gray to solve the equation because it’s had two different variables.
* Fitness function to maximize the problem by objective: F (x1, x2) = 8 – (x1 + 0.0317)2 + (x2)2, where -2 ≤ x1, x2 ≤ 2.
* We use the constraint with the objective function when he asks penalty is computed as F (x1, x2) - | x1 + x2 - 1|.
* Rank function to sort the array by ranking it to use the rank in rank fit.
* Rank fit function to rescale the fitness of individuals using a parameter SP = [1,2] and the following steps: 1 2 3 Each individual in the population is ranked in increasing order of fitness, from 1 to N. I.e., the solution with the lowest fitness will be of rank 1, while the solution with the highest fitness will be of rank N (N is the population size). The rank fitness value of the solution at rank I (Rank(I)) is computed as rank Fit = (2 − SP) +2(SP−1) × (Rank(I)−1) /N−1. Given the rank fitness computed for all solutions, apply Roulette wheel selection.
* Calculate fitness by sum the chromosome.
* Creating the Selection function to do the probability for every chromosome.
* Cumulative function to calculate the cumulative probability.
* Function of one point cross over to select the parents by creating a random number between 0 and 1 and choose the parent when the random number is less than the cumulative in array “array containing the cumulative probability for every chromosome and take the index to bring the parent from chromosome array” , creating the child by creating a cutting point calculated by generating the random number between 0 and 1 and check by probability of cross over if the random number less than the probability then we generating random number between 0 and the length of gene to take the cutting point and calc the children else we put the parent directly.
* Mutation function take the array of child’s and generate random number between 0 and 1 if the random number < probability of mutation flips the bit else keep it.
* Generation function to run the code generation by generation and calculate the highest fitness and average fitness for every generation and print the final generation and the highest fitness and average for every generation.
* Elitism to keep the highest fitness in generation to next generation.
* The main screen is:

Enter the number of bits to encode the variables:

1-Standard decoding by optimization function.

2-Standard decoding by optimization function and constraint.

3-gray decoding by optimization function.

4-gray decoding by optimization function and constraint.

5-Exit.

**the best fitness values and the average values, plotted over generations (with and without elitism): -**

**blue for the highest fitness.**

**red for the average fitness.**

Standard decoding by optimization function:

The highest fitness in 1 generation:1.9007228297425451

The average fitness in 1 generation:1.008328257297627

The highest fitness in 2 generation:1.8757350722458594

The average fitness in 2 generation:0.9993496347320074

The highest fitness in 3 generation:1.8637039884264432

The average fitness in 3 generation:0.9723716426099072

The highest fitness in 4 generation:1.82554972550586

The average fitness in 4 generation:1.0103526345124478

The highest fitness in 5 generation:1.929836401767354

The average fitness in 5 generation:1.0138378556882874

Chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.7326809197455952

The average fitness in 1 generation with elitism:0.9944068890165884

The highest fitness in 2 generation with elitism:1.8276017171262446

The average fitness in 2 generation with elitism:1.0097519150178784

The highest fitness in 3 generation with elitism:1.8979443508320542

The average fitness in 3 generation with elitism:1.0173023339594605

The highest fitness in 4 generation with elitism:1.8122595787505338

The average fitness in 4 generation with elitism:0.9813688058894732

The highest fitness in 5 generation with elitism:1.8367836991032949

The average fitness in 5 generation with elitism:1.0017841723410827

Chart, line chart

Description automatically generated

Standard decoding by optimization function and constraint:

The highest fitness in 1 generation:1.736076132890475

The average fitness in 1 generation:1.0304879612495557

The highest fitness in 2 generation:1.827419720869334

The average fitness in 2 generation:1.0037642443951398

The highest fitness in 3 generation:1.738171958177139

The average fitness in 3 generation:1.0161532583887425

The highest fitness in 4 generation:1.699091940508654

The average fitness in 4 generation:1.0124578506306576

The highest fitness in 5 generation:1.856593965673052

The average fitness in 5 generation:1.0034010256224466

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.8960037447952443

The average fitness in 1 generation with elitism:0.9753092379625266

The highest fitness in 2 generation with elitism:1.8518319574840836

The average fitness in 2 generation with elitism:0.9901912097172328

The highest fitness in 3 generation with elitism:1.777811921188487

The average fitness in 3 generation with elitism:0.9825152898069299

The highest fitness in 4 generation with elitism:1.8370162025913568

The average fitness in 4 generation with elitism:0.9901978038265266

The highest fitness in 5 generation with elitism:1.8175471080222418

The average fitness in 5 generation with elitism:0.9830650035539208

Chart, line chart

Description automatically generated

gray decoding by optimization function:

The highest fitness in 1 generation:1.8774274327731084

The average fitness in 1 generation:1.017741687433542

The highest fitness in 2 generation:1.9413285437878518

The average fitness in 2 generation:0.9961430679284834

The highest fitness in 3 generation:1.8923199810670408

The average fitness in 3 generation:1.0273960726617697

The highest fitness in 4 generation:1.9757324959196434

The average fitness in 4 generation:0.9702459746539372

The highest fitness in 5 generation:1.7422465151104567

The average fitness in 5 generation:1.0209460343036918

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.9078120455449574

The average fitness in 1 generation with elitism:0.9864917750181077

The highest fitness in 2 generation with elitism:1.8463759737398129

The average fitness in 2 generation with elitism:1.0096097159325974

The highest fitness in 3 generation with elitism:1.9905301661211796

The average fitness in 3 generation with elitism:0.988950345380105

The highest fitness in 4 generation with elitism:1.9334540804213431

The average fitness in 4 generation with elitism:0.9889441719183288

The highest fitness in 5 generation with elitism:1.712076721310866

The average fitness in 5 generation with elitism:0.9707330875410967

Chart, line chart

Description automatically generated

gray decoding by optimization function and constraint:

The highest fitness in 1 generation:1.8320257314669148

The average fitness in 1 generation:1.0002293449569057

The highest fitness in 2 generation:1.8216912582207305

The average fitness in 2 generation:0.986548117401071

The highest fitness in 3 generation:1.8762919515738767

The average fitness in 3 generation:0.9905641694956139

The highest fitness in 4 generation:1.9424515977785428

The average fitness in 4 generation:0.9945730851754667

The highest fitness in 5 generation:1.7377648941315789

The average fitness in 5 generation:0.9863021590832364

Chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.8759313413061103

The average fitness in 1 generation with elitism:0.97892765133

The highest fitness in 2 generation with elitism:1.9136977696362

The average fitness in 2 generation with elitism:1.010972202466454

The highest fitness in 3 generation with elitism:1.949335966140052

The average fitness in 3 generation with elitism:0.9753106465626533

The highest fitness in 4 generation with elitism:1.8310027017396553

The average fitness in 4 generation with elitism:0.9804091366141212

The highest fitness in 5 generation with elitism:1.9083453225485645

The average fitness in 5 generation with elitism:1.0089745055895363

Chart, line chart

Description automatically generated