**Main solution steps:**

* Initialize a chromosome by real value it’s taken a pop size that include a size of population and the size of the chromosome, and it’s taken a minimum of real value and the maximum.
* 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.
* Tournament Selection is a Selection Strategy used for selecting the fittest candidates from the current generation in a Genetic Algorithm by take the k value from the user and select random k ”k is integer value and it must be > 0 to be possible to select” from the population array and take the maximum fit from the k selection to be a parent and so on “ the function of the tournament in the function of the one point cross over”.
* 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.
* Arithmetic crossover operator linearly combines the two parent chromosomes. In an arithmetic crossover, randomly two chromosomes are selected for crossover, and by a linear combination of these chromosomes, two off springs are produced and the equation and the algorithm of the arithmetic crossover is : Child1=a.P1gene + (1-a).P2gene,Child2=a.P2gene+ (1-a).P1gene and before do that we check if the random number < pcross do the algorithm else put the parent in the next generation ” the function of the arithmetic in the function of the one point cross over”.
* Bitwise 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.
* Gaussian mutation consists in adding a random value from a Gaussian distribution to each element of an individual's vector to create a new offspring and the equation and the algorithm of this is:

(1/(sqrt(2 π σ 2))\*e(-(x-a)\*\*2)/2σ\*\*2 , a is a mean and σ is a standard deviation.

* 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.
* We can use the tournament selection in assignment 2 to make it more effective and more accuracy. the tournament selection is most accuracy of the Roulette wheel selection, arithmetic cross over more accuracy to the real value and the Gaussian mutation likewise.
* The main screen is:

Enter the number of bits to encode the variables:

1-binary

2-real value

enter your choice:

1-Roulette wheel

2-Tournment

Enter selection choice:

enter number of the tournament” K” selection:

1-one point cross over

2-arithmatic cross over

enter cross over choice:

1-Bitwise mutation

2-Gaussian mutation

enter mutation choice:

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.**

Enter the number of bits to encode the variables:4

Real value, R\_max=4,R\_min=-4,Tournmant,k=3, arithmetic crossover, Gaussian mutation

The highest fitness in 1 generation:1.950925005693609

The average fitness in 1 generation:0.9892217219520558

The highest fitness in 2 generation:1.8100646891205854

The average fitness in 2 generation:0.9871743764012161

The highest fitness in 3 generation:1.8537645213055423

The average fitness in 3 generation:0.9889054739339138

The highest fitness in 4 generation:1.90777254215756

The average fitness in 4 generation:1.0197750905472374

The highest fitness in 5 generation:1.8899233811219929

The average fitness in 5 generation:1.0119975637071155

Chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.9094350037774313

The average fitness in 1 generation with elitism:0.9970073564313667

The highest fitness in 2 generation with elitism:1.8300396802387395

The average fitness in 2 generation with elitism:1.0299626782910338

The highest fitness in 3 generation with elitism:1.7327116989926712

The average fitness in 3 generation with elitism:0.9975898964952686

The highest fitness in 4 generation with elitism:1.8123264088434405

The average fitness in 4 generation with elitism:0.9866603279329692

The highest fitness in 5 generation with elitism:1.802883374837922

The average fitness in 5 generation with elitism:1.009691775675829

Chart, line chart

Description automatically generated

Enter the number of bits to encode the variables:4

Binary, Tournament, k=3, one point crossover, Bitwise mutation

Standard decoding by optimization function:

The highest fitness in 1 generation:1.9694411552749318

The average fitness in 1 generation:1.0234590758708557

The highest fitness in 2 generation:1.7701069343968683

The average fitness in 2 generation:0.9890026647639637

The highest fitness in 3 generation:1.7334607580195516

The average fitness in 3 generation:0.9814354837186527

The highest fitness in 4 generation:1.8666353801074398

The average fitness in 4 generation:1.0124577363744738

The highest fitness in 5 generation:1.9322949663185796

The average fitness in 5 generation:0.9831461533513051

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.8371051135020722

The average fitness in 1 generation with elitism:0.9862326944104195

The highest fitness in 2 generation with elitism:1.84652451340168

The average fitness in 2 generation with elitism:1.0266357702541724

The highest fitness in 3 generation with elitism:1.7964050226276378

The average fitness in 3 generation with elitism:1.0028342157840202

The highest fitness in 4 generation with elitism:1.7566529088328342

The average fitness in 4 generation with elitism:0.976323431866239

The highest fitness in 5 generation with elitism:1.7721325763402318

The average fitness in 5 generation with elitism:0.9881292138553006

Chart

Description automatically generated

Standard decoding by optimization function and constraint:

The highest fitness in 1 generation:1.7100652120133715

The average fitness in 1 generation:0.9612217823537875

The highest fitness in 2 generation:1.7918883287578404

The average fitness in 2 generation:1.015573874593162

The highest fitness in 3 generation:1.6236996940981256

The average fitness in 3 generation:0.9846986743503289

The highest fitness in 4 generation:1.76222170298755

The average fitness in 4 generation:0.9999237168217285

The highest fitness in 5 generation:1.8826941025476502

The average fitness in 5 generation:0.9937402802996391

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.9349150594538926

The average fitness in 1 generation with elitism:1.0037772553103599

The highest fitness in 2 generation with elitism:1.9482872961460362

The average fitness in 2 generation with elitism:1.0413996644222796

The highest fitness in 3 generation with elitism:1.9040058669362545

The average fitness in 3 generation with elitism:1.0126270356485636

The highest fitness in 4 generation with elitism:1.9748835184750932

The average fitness in 4 generation with elitism:1.02353630065476

The highest fitness in 5 generation with elitism:1.9111926935465504

The average fitness in 5 generation with elitism:1.0000272163370814

Chart

Description automatically generated

gray decoding by optimization function:

The highest fitness in 1 generation:1.807102961749805

The average fitness in 1 generation:0.9801808403436043

The highest fitness in 2 generation:1.8450585757678408

The average fitness in 2 generation:0.9964122951685004

The highest fitness in 3 generation:1.9312689612745586

The average fitness in 3 generation:0.9941127205360504

The highest fitness in 4 generation:1.8149097077625636

The average fitness in 4 generation:1.0004418136572781

The highest fitness in 5 generation:1.799379357369277

The average fitness in 5 generation:0.9958068281027237

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.6654174548581004

The average fitness in 1 generation with elitism:0.9697364837448118

The highest fitness in 2 generation with elitism:1.9615082832010549

The average fitness in 2 generation with elitism:0.9882833349297341

The highest fitness in 3 generation with elitism:1.9287177762472847

The average fitness in 3 generation with elitism:1.0241223144614593

The highest fitness in 4 generation with elitism:1.9106612281421447

The average fitness in 4 generation with elitism:1.0116073028880521

The highest fitness in 5 generation with elitism:1.9782139487664845

The average fitness in 5 generation with elitism:0.9903673024365653

Chart

Description automatically generated

gray decoding by optimization function and constraint:

The highest fitness in 1 generation:1.7094061928385402

The average fitness in 1 generation:1.0043439166389012

The highest fitness in 2 generation:1.9128923346855982

The average fitness in 2 generation:0.974409632890601

The highest fitness in 3 generation:1.932391203923086

The average fitness in 3 generation:1.006408456367157

The highest fitness in 4 generation:1.8462434294736578

The average fitness in 4 generation:1.000537524770641

The highest fitness in 5 generation:1.7328868628752934

The average fitness in 5 generation:0.9696164944950709

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.8263103418566096

The average fitness in 1 generation with elitism:1.0057423638644292

The highest fitness in 2 generation with elitism:1.8268374769776623

The average fitness in 2 generation with elitism:0.9716226605272097

The highest fitness in 3 generation with elitism:1.66407872296903

The average fitness in 3 generation with elitism:0.9915868091477527

The highest fitness in 4 generation with elitism:1.9074888879307101

The average fitness in 4 generation with elitism:0.9661602513779035

The highest fitness in 5 generation with elitism:1.8703348364427588

The average fitness in 5 generation with elitism:1.0026119820701727

Chart, line chart

Description automatically generated

Enter the number of bits to encode the variables:4

Binary, Roulette wheel, k=3, one point crossover, Bitwise mutation

Standard decoding by optimization function:

The highest fitness in 1 generation:1.801131543322656

The average fitness in 1 generation:1.010834012544578

The highest fitness in 2 generation:1.895135497668831

The average fitness in 2 generation:1.0037475674403085

The highest fitness in 3 generation:1.5983893203454655

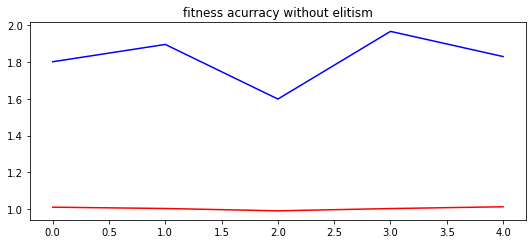
The average fitness in 3 generation:0.9910676904016461

The highest fitness in 4 generation:1.9661371058213841

The average fitness in 4 generation:1.0033893118147972

The highest fitness in 5 generation:1.829311516634415

The average fitness in 5 generation:1.0130955124153194



The highest fitness in 1 generation with elitism:1.902346907978839

The average fitness in 1 generation with elitism:0.9946703543563908

The highest fitness in 2 generation with elitism:1.8671081535194731

The average fitness in 2 generation with elitism:0.9893527341318542

The highest fitness in 3 generation with elitism:1.7914517329065005

The average fitness in 3 generation with elitism:0.978820844737474

The highest fitness in 4 generation with elitism:1.939733507677743

The average fitness in 4 generation with elitism:0.9837517412371428

The highest fitness in 5 generation with elitism:1.6371262476101927

The average fitness in 5 generation with elitism:0.9498069715912264

Chart, line chart

Description automatically generated

Standard decoding by optimization function and constraint:

The highest fitness in 1 generation:1.893095595048367

The average fitness in 1 generation:0.9785564413174046

The highest fitness in 2 generation:1.873141355797755

The average fitness in 2 generation:1.001641313885906

The highest fitness in 3 generation:1.8093715629002294

The average fitness in 3 generation:0.997734037199445

The highest fitness in 4 generation:1.6852155443778478

The average fitness in 4 generation:1.0041741833878512

The highest fitness in 5 generation:1.7839496811609512

The average fitness in 5 generation:0.9963518717548536

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.9147188306747354

The average fitness in 1 generation with elitism:0.9895961186803632

The highest fitness in 2 generation with elitism:1.802103222044218

The average fitness in 2 generation with elitism:1.0252416284130206

The highest fitness in 3 generation with elitism:1.8270809929362783

The average fitness in 3 generation with elitism:1.0031613872210634

The highest fitness in 4 generation with elitism:1.8957688686298706

The average fitness in 4 generation with elitism:0.9935938683015946

The highest fitness in 5 generation with elitism:1.9241893419446334

The average fitness in 5 generation with elitism:0.9712774278282229

Chart

Description automatically generated

gray decoding by optimization function:

The highest fitness in 1 generation:1.8489084650024563

The average fitness in 1 generation:0.9819466250474148

The highest fitness in 2 generation:1.8919991374592444

The average fitness in 2 generation:1.008742374977596

The highest fitness in 3 generation:1.9432580590817212

The average fitness in 3 generation:0.9963984841728358

The highest fitness in 4 generation:1.7200290345859879

The average fitness in 4 generation:0.9904746131940059

The highest fitness in 5 generation:1.9046780658630873

The average fitness in 5 generation:1.0092728758800404

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.9656090146183212

The average fitness in 1 generation with elitism:0.9867859781734454

The highest fitness in 2 generation with elitism:1.8697303889004009

The average fitness in 2 generation with elitism:0.9938220504999252

The highest fitness in 3 generation with elitism:1.9531480991520311

The average fitness in 3 generation with elitism:0.9977023438284628

The highest fitness in 4 generation with elitism:1.7951467476189584

The average fitness in 4 generation with elitism:0.98149180801589

The highest fitness in 5 generation with elitism:1.8337360134127925

The average fitness in 5 generation with elitism:1.0169587601646464

Chart, line chart

Description automatically generated

gray decoding by optimization function and constraint:

The highest fitness in 1 generation:1.7781812883629615

The average fitness in 1 generation:1.0181370447729403

The highest fitness in 2 generation:1.7235267089015145

The average fitness in 2 generation:1.0007223898147408

The highest fitness in 3 generation:1.7762258920331657

The average fitness in 3 generation:0.9937135615507664

The highest fitness in 4 generation:1.9390382984772327

The average fitness in 4 generation:0.9999801985949507

The highest fitness in 5 generation:1.9522155749491386

The average fitness in 5 generation:0.9978581733517802

Chart, line chart

Description automatically generated

The highest fitness in 1 generation with elitism:1.8663703956818984

The average fitness in 1 generation with elitism:1.0040577427492314

The highest fitness in 2 generation with elitism:1.7912774290798805

The average fitness in 2 generation with elitism:1.0133232281456432

The highest fitness in 3 generation with elitism:1.8197832619327823

The average fitness in 3 generation with elitism:1.002323246305391

The highest fitness in 4 generation with elitism:1.8480133366451554

The average fitness in 4 generation with elitism:1.021716586600057

The highest fitness in 5 generation with elitism:1.9058330861757418

The average fitness in 5 generation with elitism:0.9895212449821243

Chart

Description automatically generated