Backtracking Search Optimization Algorithm

Group 2

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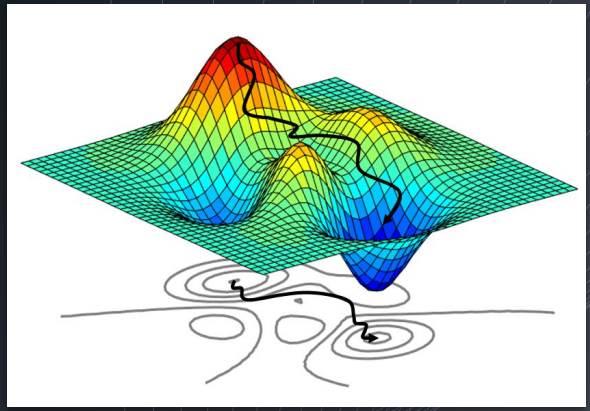
Optimization

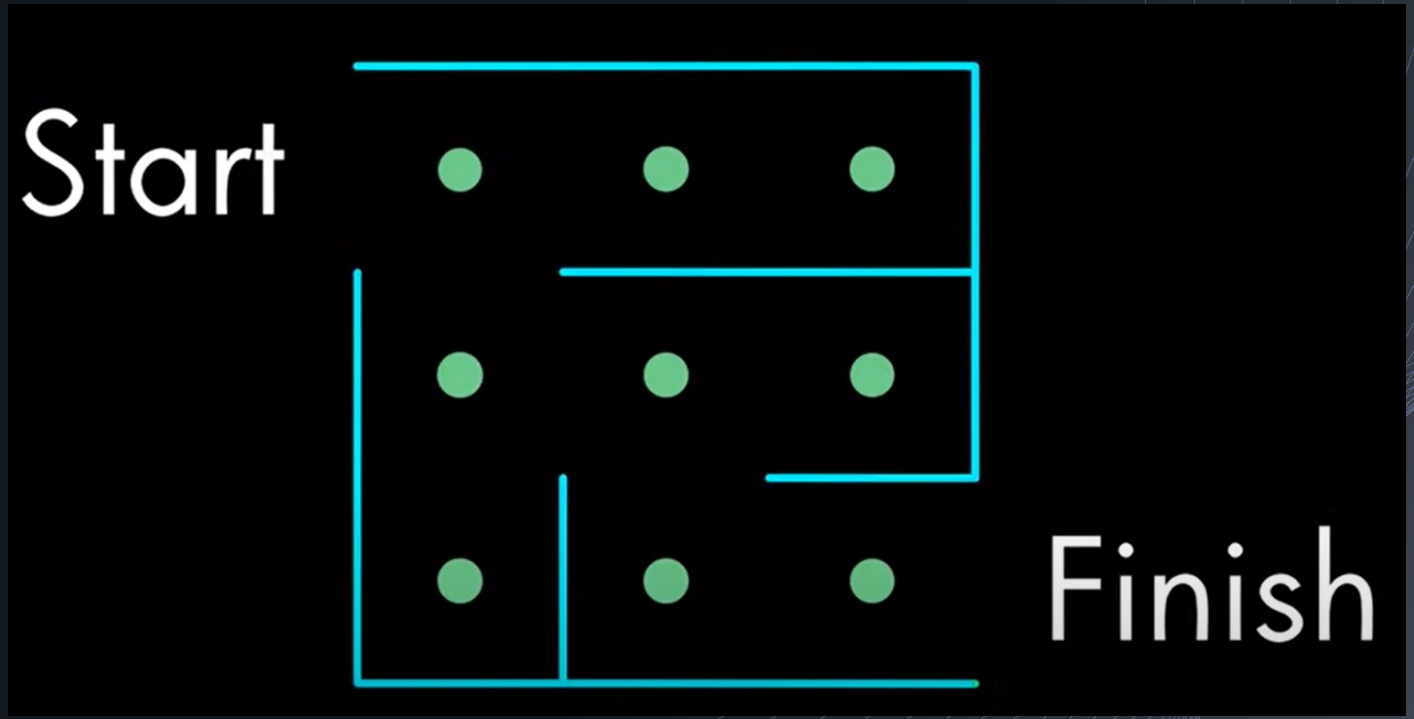


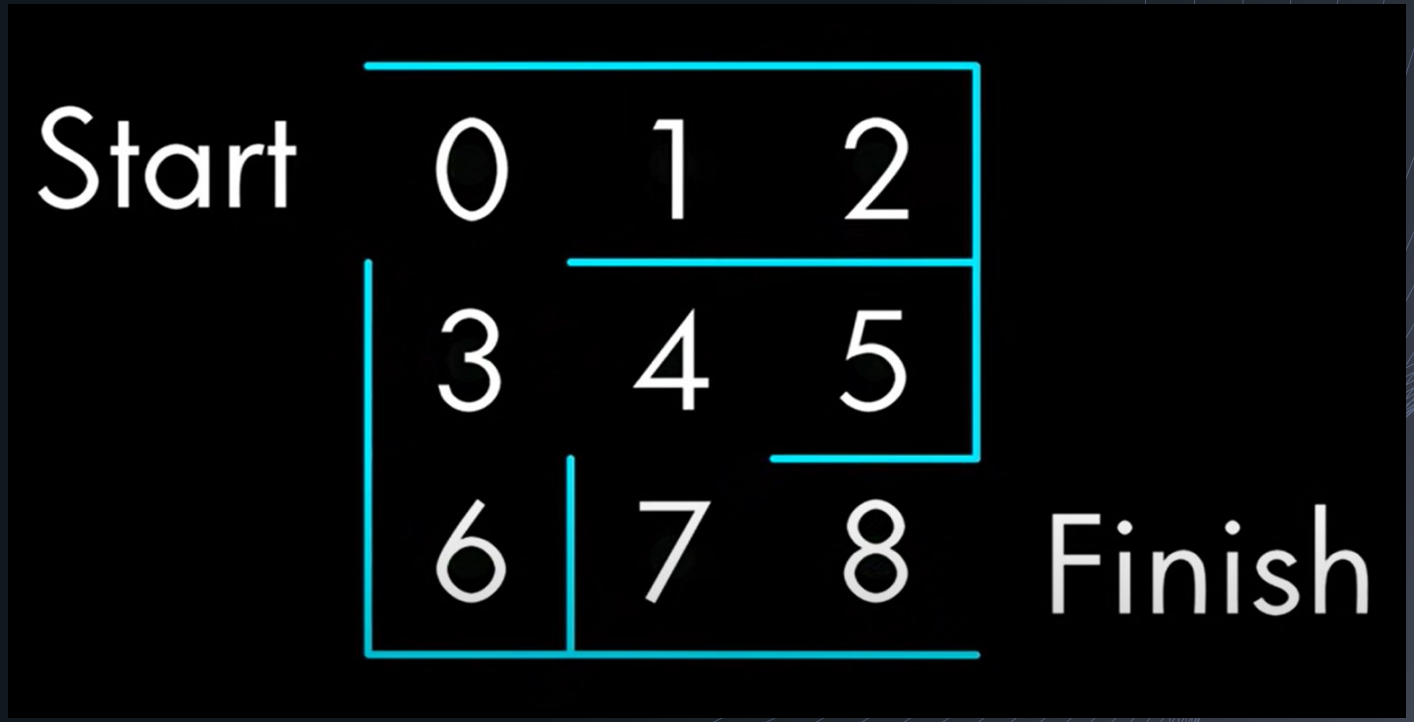
Optimization is a very important research area in applied mathematics.

Optimization algorithms aim to find the best values for a system's parameters under various conditions.

Evolutionary algorithms

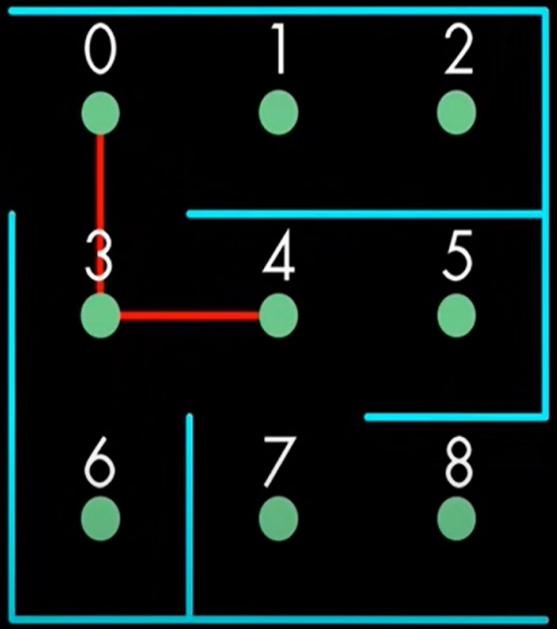
What is Backtracking?


Start
Finish


Start
0
1
2
3
4
5
6
7
8
Finish

Path:

0 3 4



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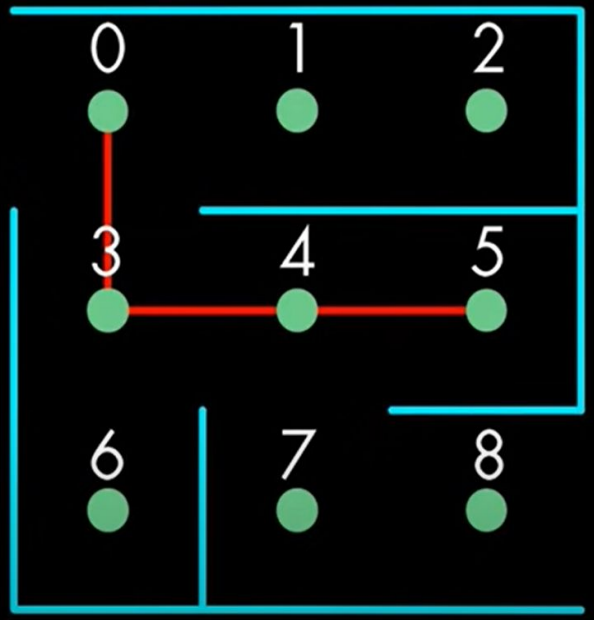
Path:

0 3 4 5



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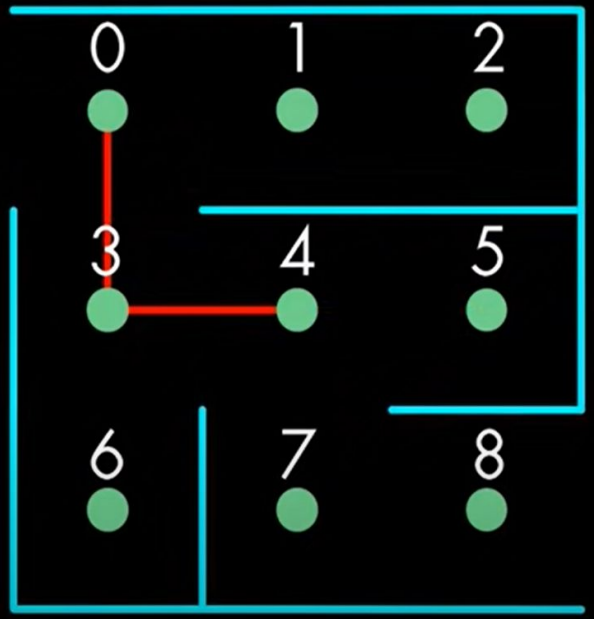

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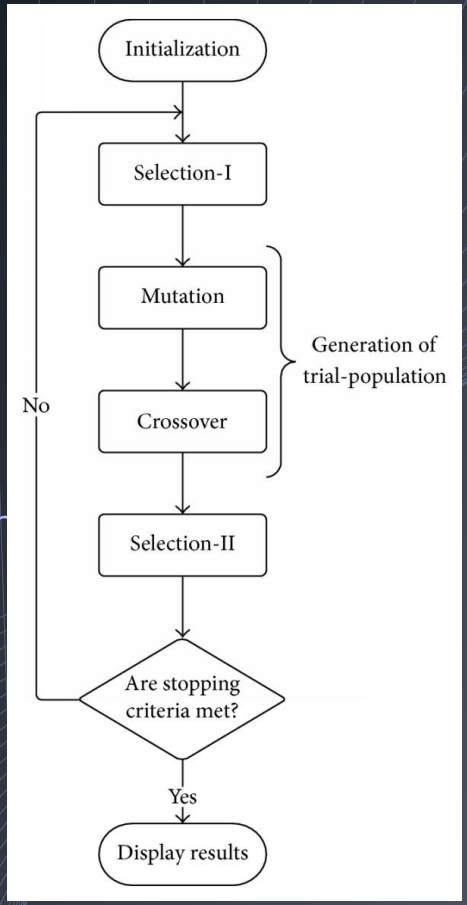
Backtracking Search Algorithm

1. Algorithm
2. Implementation

Backtracking Search Algorithm

BSA is one of the new population based evolutionary algorithms.

It is based on an iterative process which tries to minimize the objective functior



Stages

There are 5 stages to implement the algorithm, which are following:

1. Initialization
2. Selection-I
3. Mutation
4. Crossover
5. Selection-II

1. Initialization

BSA initializes the population P with equation:

```
for i from 1 to N do
    for j from 1 to D do
        P_{i,j} = rnd · (up_j − low_j) + low_j // Initialization of population, P.
        oldP_{i,j} = rnd · (up_j − low_j) + low_j // Initialization of oldP.
    end
    fitnessP_i = ObjFun(P_i) // Initial-fitness values of P
end
```

Where:

- **N** → population size
- **D** → problem dimension
- **rnd** → uniform distribution function U(0,1)
- $\mathbf{P_i}$ → population member
- $\mathbf{low_j}$, $\mathbf{up_j}$ → bounds of solution space

2. Selection-I

The following equation gives a chance to BSA to redesign at the beginning of each iteration:

```
// SELECTION-I
if (a < b|a, b ~ U(0, 1)) then oldP := P end
oldP := permuting(oldP) // 'permuting' arbitrary changes in positions of two
individuals in oldP.
```

Where:

- **a,b** → random number of uniform distribution function U(0,1)
- **P** → current population
- **oldP** → old population
- **permute** → random shuffle function

3. Mutation

The mutant members of BSA are generated by using the following function:

$$mutant = P + 3 \cdot rndn \cdot (oldP - P)$$

Where:

rndn → random number of normal distribution function N(0,1)

4. Crossover

BSA's crossover process generates the final form of the trial population T. The crossover step includes two steps. The first strategy uses mixrate.

(0) $\text{map}_{(1:N,1:D)} = 1$
(1) **if** $a < b \mid a, b \sim U(0,1)$ **then**
(2) **for** i from 1 to N **do**
(3) $\text{map}_{i,u_{(1:\lceil \text{mixrate} \cdot \text{rnd} \cdot D \rceil)}} = 0 \mid u = \text{permuting } ((1, 2, 3, \ldots, D))$
(4) **end**
(5) **else**
(6) **for** i from 1 to N **do**, $\text{map}_{i,\text{randi}(D)} = 0$, **end**
(7) **end**
(8) T := Mutant
(9) **for** i from 1 to N **do**
(10) **for** j from 1 to D **do**
(11) **if** $\text{map}_{i,j} = 1$ **then** $T_{i,j} := P_{i,j}$
(12) **end**
(13) **end**

4. Crossover

The second strategy allows only one randomly chosen individual to mutate in each trial

Input: T, Search sapce limits
Output: T
for i from 1 to N **do**
    for j from 1 to D **do**
        if $(T_{i,j} < \text{low}_j)$ or $(T_{i,j} > \text{up}_j)$ **then**
            $T_{i,j} = \text{rnd} \cdot \left(\text{up}_j - \text{low}_j\right) + \text{low}_j$
        end
    end
end

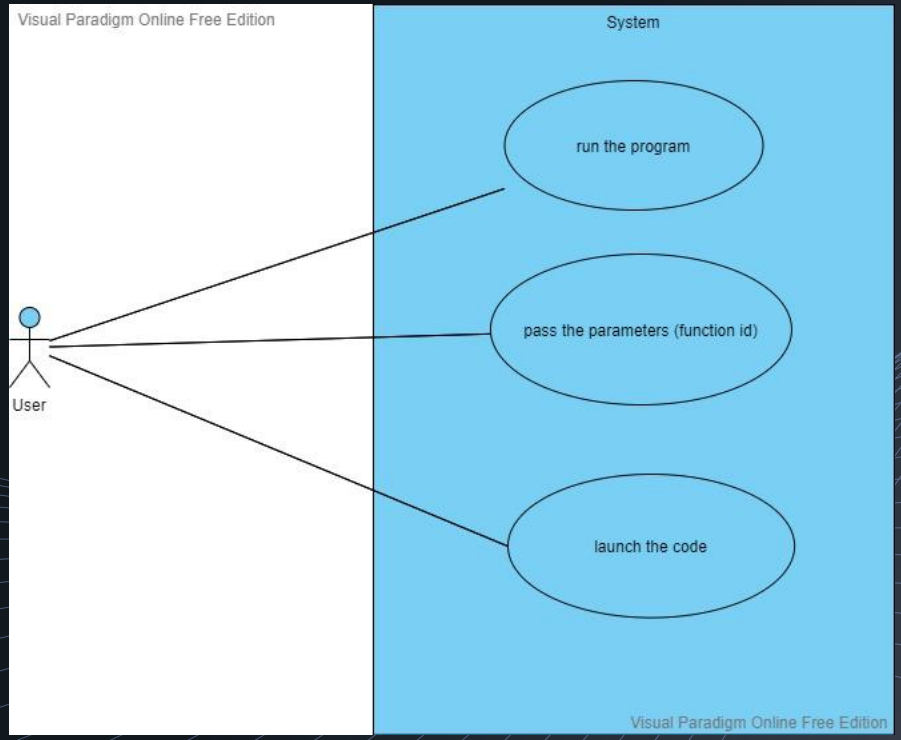
5. Selection-II

In selection-II process of BSA, Pis values are updated by a greedy selection strategy

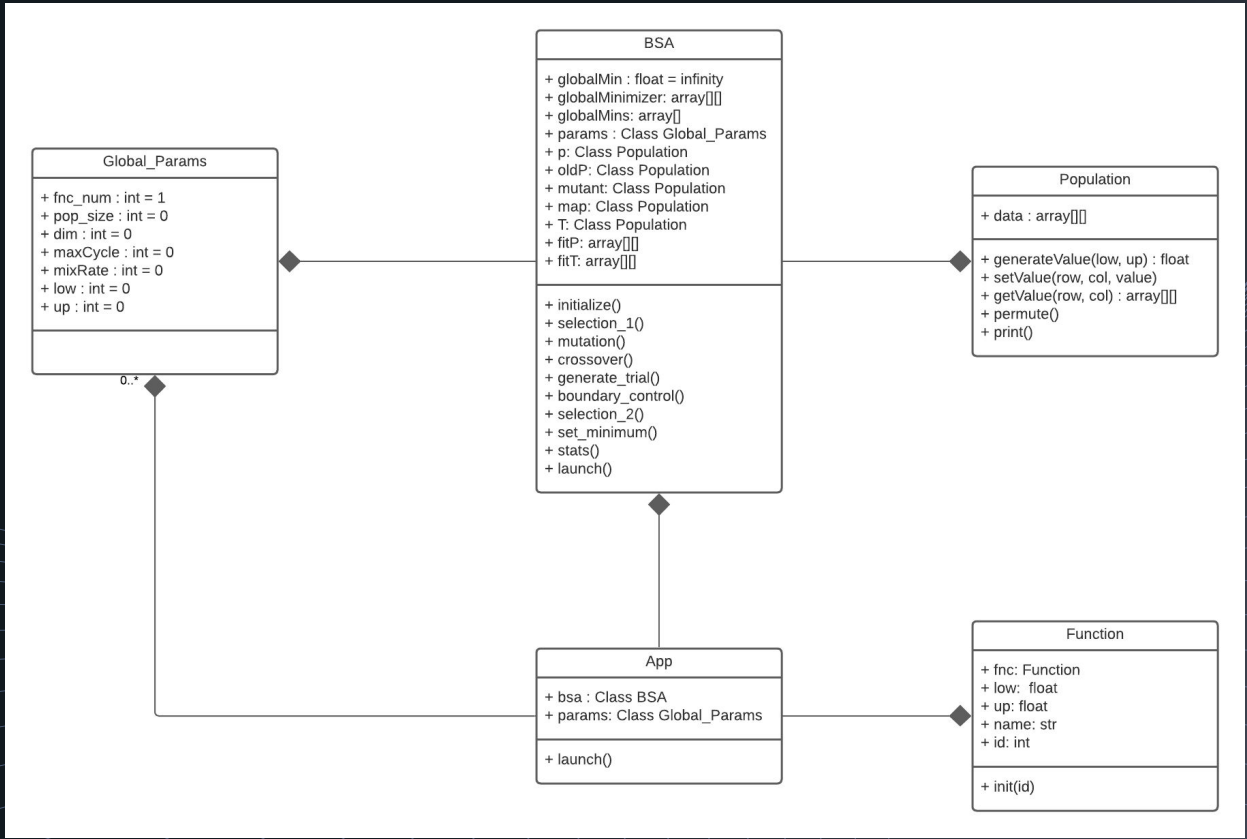
```
// SELECTION-II
fitnessT = ObjFnc(T)
for i from 1 to N do
    if fitnessT_i < fitnessP_i then
        fitnessP_i := fitnessT_i
        P_i := T_i
    end
end
fitnessP_best = min(fitnessP) | best ∈ {1, 2, 3, ..., N}
if fitnessP_best < globalminimum then
    globalminimum:=fitnessP_best
    globalminimizer:=P_best
    // Export globalminimum and globalminimizer
end
```

Implementation

Use Case Diagram



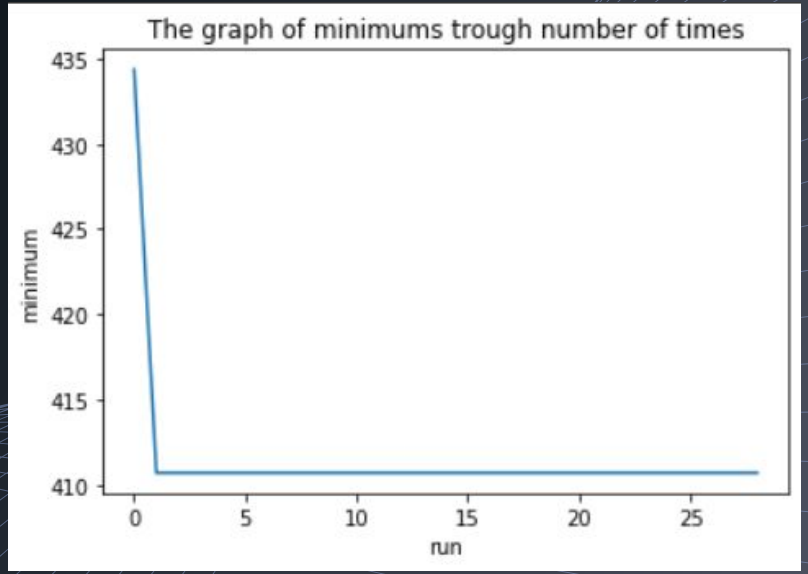
Class diagram



Result

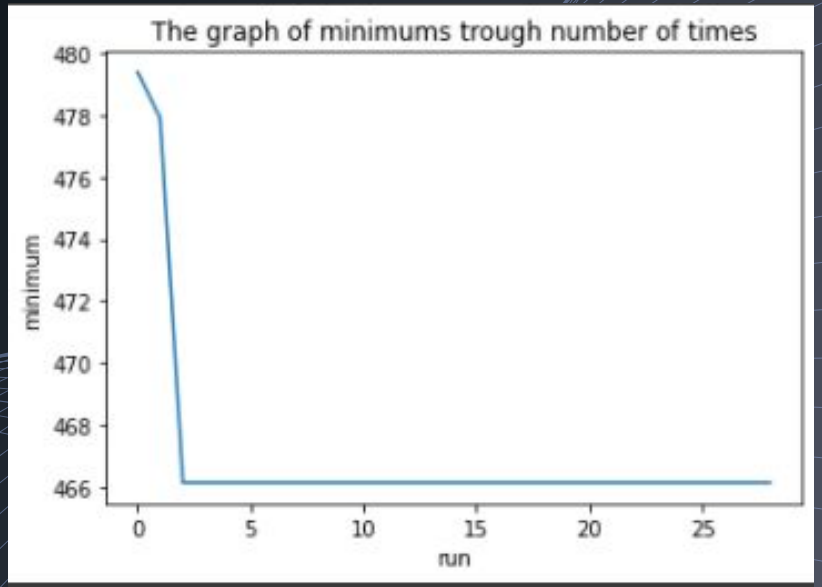
Ackley

```
Backtracking Search Optimization Algorithm
---------------------------
The list of functions:
1. Ackley function
2. Rastrigin function
3. Rosebrock function
4. Schewel function
---------------------------
Please choose the function from the list: 2
-------------------------------------------------------------------------
BSA: 0 ----------------------------------> 434.36929290221286
BSA: 1 ----------------------------------> 410.69650441113856
BSA: 2 ----------------------------------> 410.69650441113856
BSA: 3 ----------------------------------> 410.69650441113856
BSA: 4 ----------------------------------> 410.69650441113856
BSA: 5 ----------------------------------> 410.69650441113856
BSA: 6 ----------------------------------> 410.69650441113856
BSA: 7 ----------------------------------> 410.69650441113856
BSA: 8 ----------------------------------> 410.69650441113856
BSA: 9 ----------------------------------> 410.69650441113856
BSA: 10 ----------------------------------> 410.69650441113856
BSA: 11 ----------------------------------> 410.69650441113856
BSA: 12 ----------------------------------> 410.69650441113856
BSA: 13 ----------------------------------> 410.69650441113856
BSA: 14 ----------------------------------> 410.69650441113856
BSA: 15 ----------------------------------> 410.69650441113856
BSA: 16 ----------------------------------> 410.69650441113856
BSA: 17 ----------------------------------> 410.69650441113856
BSA: 18 ----------------------------------> 410.69650441113856
BSA: 19 ----------------------------------> 410.69650441113856
BSA: 20 ----------------------------------> 410.69650441113856
BSA: 21 ----------------------------------> 410.69650441113856
BSA: 22 ----------------------------------> 410.69650441113856
BSA: 23 ----------------------------------> 410.69650441113856
BSA: 24 ----------------------------------> 410.69650441113856
BSA: 25 ----------------------------------> 410.69650441113856
BSA: 26 ----------------------------------> 410.69650441113856
BSA: 27 ----------------------------------> 410.69650441113856
BSA: 28 ----------------------------------> 410.69650441113856
BSA: 29 ----------------------------------> 410.69650441113856
Mean:     411.5128074625549
Variance:         19.324169480797927
Standard deviation:       4.395926464443864
Best:     410.69650441113856
Worst:    434.36929290221286
```



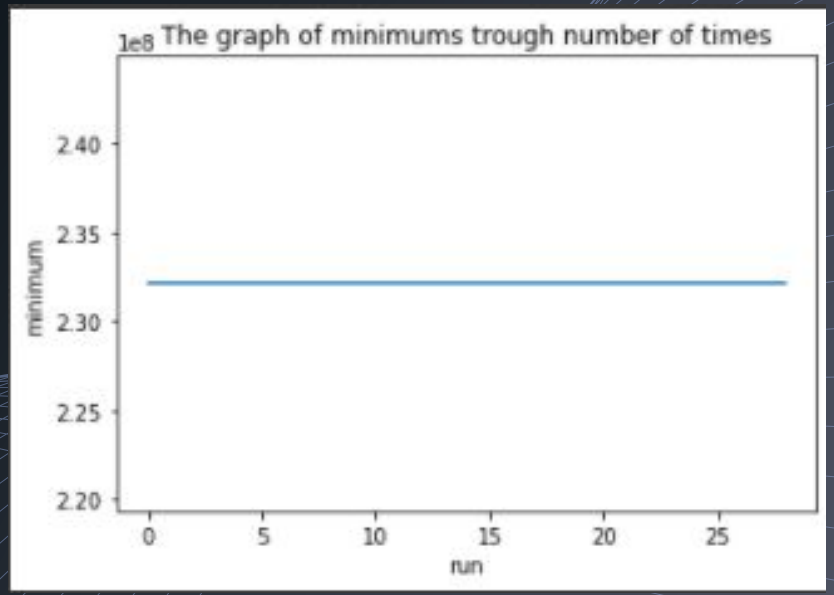
Rastrigin

```
Backtracking Search Optimization Algorithm
--------------------------
The list of functions:
1. Ackley function
2. Rastrigin function
3. Rosebrock function
4. Schewel function
--------------------------
Please choose the function from the list: 2
------------------------------------------------------------------------
BSA: 0 ----------------------------------> 479.374023767896
BSA: 1 ----------------------------------> 477.8923950417452
BSA: 2 ----------------------------------> 466.1461118640759
BSA: 3 ----------------------------------> 466.1461118640759
BSA: 4 ----------------------------------> 466.1461118640759
BSA: 5 ----------------------------------> 466.1461118640759
BSA: 6 ----------------------------------> 466.1461118640759
BSA: 7 ----------------------------------> 466.1461118640759
BSA: 8 ----------------------------------> 466.1461118640759
BSA: 9 ----------------------------------> 466.1461118640759
BSA: 10 ----------------------------------> 466.1461118640759
BSA: 11 ----------------------------------> 466.1461118640759
BSA: 12 ----------------------------------> 466.1461118640759
BSA: 13 ----------------------------------> 466.1461118640759
BSA: 14 ----------------------------------> 466.1461118640759
BSA: 15 ----------------------------------> 466.1461118640759
BSA: 16 ----------------------------------> 466.1461118640759
BSA: 17 ----------------------------------> 466.1461118640759
BSA: 18 ----------------------------------> 466.1461118640759
BSA: 19 ----------------------------------> 466.1461118640759
BSA: 20 ----------------------------------> 466.1461118640759
BSA: 21 ----------------------------------> 466.1461118640759
BSA: 22 ----------------------------------> 466.1461118640759
BSA: 23 ----------------------------------> 466.1461118640759
BSA: 24 ----------------------------------> 466.1461118640759
BSA: 25 ----------------------------------> 466.1461118640759
BSA: 26 ----------------------------------> 466.1461118640759
BSA: 27 ----------------------------------> 466.1461118640759
BSA: 28 ----------------------------------> 466.1461118640759
BSA: 29 ----------------------------------> 466.1461118640759
Mean:    467.0072910048169
Variance:        10.40877021300879
Standard deviation:      3.226262576575067
Best:    466.1461118640759
Worst:   479.374023767896
```



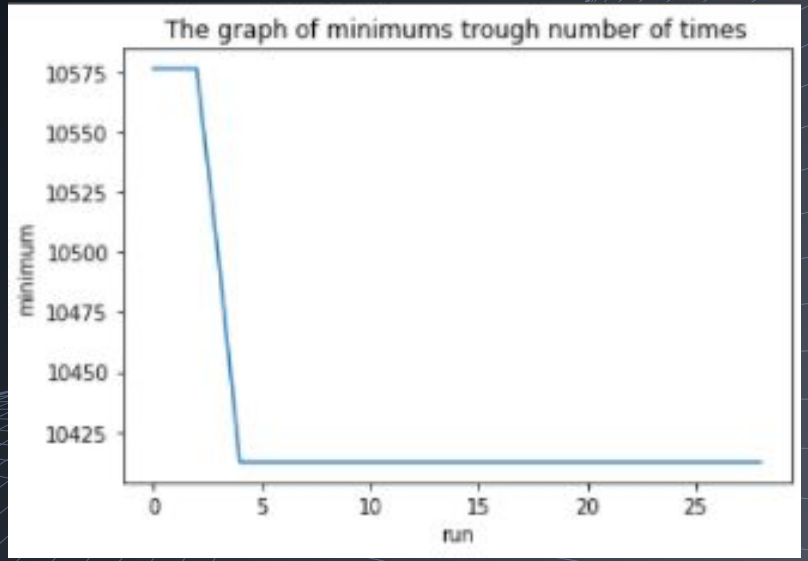
Rosenbrock

```
Backtracking Search Optimization Algorithm
--------------------------
The list of functions:
1. Ackley function
2. Rastrigin function
3. Rosebrock function
4. Schewel function
--------------------------
Please choose the function from the list: 3
------------------------------------------------------------
BSA: 0 ----------------------------------> 232144172.58000427
BSA: 1 ----------------------------------> 232144172.58000427
BSA: 2 ----------------------------------> 232144172.58000427
BSA: 3 ----------------------------------> 232144172.58000427
BSA: 4 ----------------------------------> 232144172.58000427
BSA: 5 ----------------------------------> 232144172.58000427
BSA: 6 ----------------------------------> 232144172.58000427
BSA: 7 ----------------------------------> 232144172.58000427
BSA: 8 ----------------------------------> 232144172.58000427
BSA: 9 ----------------------------------> 232144172.58000427
BSA: 10 ----------------------------------> 232144172.58000427
BSA: 11 ----------------------------------> 232144172.58000427
BSA: 12 ----------------------------------> 232144172.58000427
BSA: 13 ----------------------------------> 232144172.58000427
BSA: 14 ----------------------------------> 232144172.58000427
BSA: 15 ----------------------------------> 232144172.58000427
BSA: 16 ----------------------------------> 232144172.58000427
BSA: 17 ----------------------------------> 232144172.58000427
BSA: 18 ----------------------------------> 232144172.58000427
BSA: 19 ----------------------------------> 232144172.58000427
BSA: 20 ----------------------------------> 232144172.58000427
BSA: 21 ----------------------------------> 232144172.58000427
BSA: 22 ----------------------------------> 232144172.58000427
BSA: 23 ----------------------------------> 232144172.58000427
BSA: 24 ----------------------------------> 232144172.58000427
BSA: 25 ----------------------------------> 232144172.58000427
BSA: 26 ----------------------------------> 232144172.58000427
BSA: 27 ----------------------------------> 232144172.58000427
BSA: 28 ----------------------------------> 232144172.58000427
BSA: 29 ----------------------------------> 232144172.58000427
Mean:    232144172.58000427
Variance:        0.0
Standard deviation:      0.0
Best:    232144172.58000427
Worst:   232144172.58000427
```



Schwefel

```
Backtracking Search Optimization Algorithm
--------------------------
The list of functions:
1. Ackley function
2. Rastrigin function
3. Rosebrock function
4. Schewel function
--------------------------
Please choose the function from the list: 4
------------------------------------------------------------------------
BSA: 0 ----------------------------------> 10576.57188878187
BSA: 1 ----------------------------------> 10576.57188878187
BSA: 2 ----------------------------------> 10576.57188878187
BSA: 3 ----------------------------------> 10498.421395002684
BSA: 4 ----------------------------------> 10412.334544345376
BSA: 5 ----------------------------------> 10412.334544345376
BSA: 6 ----------------------------------> 10412.334544345376
BSA: 7 ----------------------------------> 10412.334544345376
BSA: 8 ----------------------------------> 10412.334544345376
BSA: 9 ----------------------------------> 10412.334544345376
BSA: 10 ----------------------------------> 10412.334544345376
BSA: 11 ----------------------------------> 10412.334544345376
BSA: 12 ----------------------------------> 10412.334544345376
BSA: 13 ----------------------------------> 10412.334544345376
BSA: 14 ----------------------------------> 10412.334544345376
BSA: 15 ----------------------------------> 10412.334544345376
BSA: 16 ----------------------------------> 10412.334544345376
BSA: 17 ----------------------------------> 10412.334544345376
BSA: 18 ----------------------------------> 10412.334544345376
BSA: 19 ----------------------------------> 10412.334544345376
BSA: 20 ----------------------------------> 10412.334544345376
BSA: 21 ----------------------------------> 10412.334544345376
BSA: 22 ----------------------------------> 10412.334544345376
BSA: 23 ----------------------------------> 10412.334544345376
BSA: 24 ----------------------------------> 10412.334544345376
BSA: 25 ----------------------------------> 10412.334544345376
BSA: 26 ----------------------------------> 10412.334544345376
BSA: 27 ----------------------------------> 10412.334544345376
BSA: 28 ----------------------------------> 10412.334544345376
BSA: 29 ----------------------------------> 10412.334544345376
Mean:    10432.293126551127
Variance:        2742.1663097321125
Standard deviation:      52.365697834862395
Best:    10412.334544345376
Worst:   10576.57188878187
```



Conclusion

BSA can solve a greater number of benchmark problems and can achieve statistically better results than the comparison algorithms.

- Problem solving ability
- Efficiency

References

1. P. Civicioglu, “Backtracking search optimization algorithm for numerical optimization problems,” Applied Mathematics and Computation, vol. 219, no. 15, 2013.
2. Dr. Ahmed Fouad Ali “Backtracking Search Optimization Algorithm (BSA)”
3. Department of Electrical and Electronics Engineering, Faculty of Engineering, Nuh Naci Yazgan University, 38040 Kayseri, Turkey. Department of Electricity and Energy, Vocational College, Erciyes University, 38039 Kayseri, Turkey. Department of Computer Programming, Vocational College, Nevsehir University, 50300 Nevsehir, Turkey

Thank you for your attention

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