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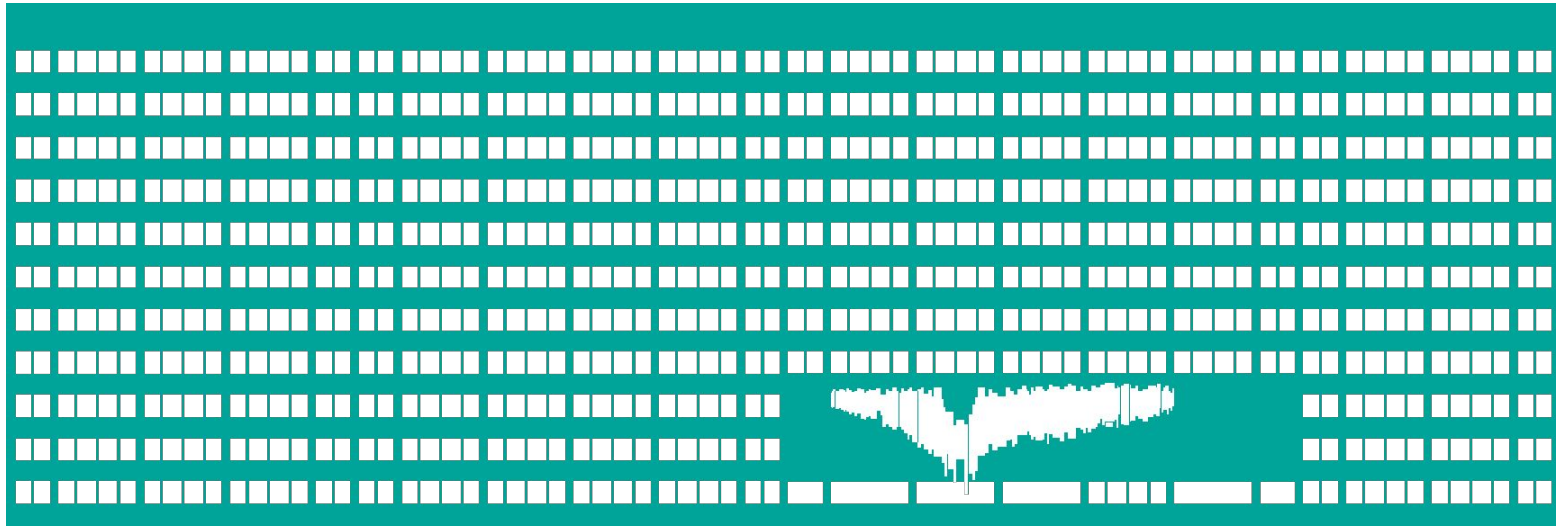

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Biologically inspired algorithms
Exercise 3

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Content

- Simulated annealing algorithm

Simulated Annealing – Control parameters

- T_0 … initial temperature (higher values, for example, 100, 200)
- T_{min} … minimal temperature (final temperature, usually set to values close to 0)
- α… cooling constant (values between 0 and 1, usually set to values from 0.9 to 0.99)

Simulated Annealing – Pseudocode

```
# Setting of control parameters
#--------------------------------
T_0 = 100
T_min = 0.5
alpha = 0.95
#--------------------------------

T = T_0

# Generation of initial solution
#--------------------------------
x = generate initial solution
Evaluate x
```

```
# Main loop
#-------------------------------------------------------

while T > T_min:

  x_1 = generate neighbour of x in normal distribution

  Evaluate x_1

  if f(x_1) < f(x):

    x = x_1

  else:

    r = random number in uniform distribution

    if r < e^-(f(x_1)-f(x))/T :
       x = x_1

  T = T*alpha
```

Simulated Annealing – Pseudocode

- Important row in pseudocode:

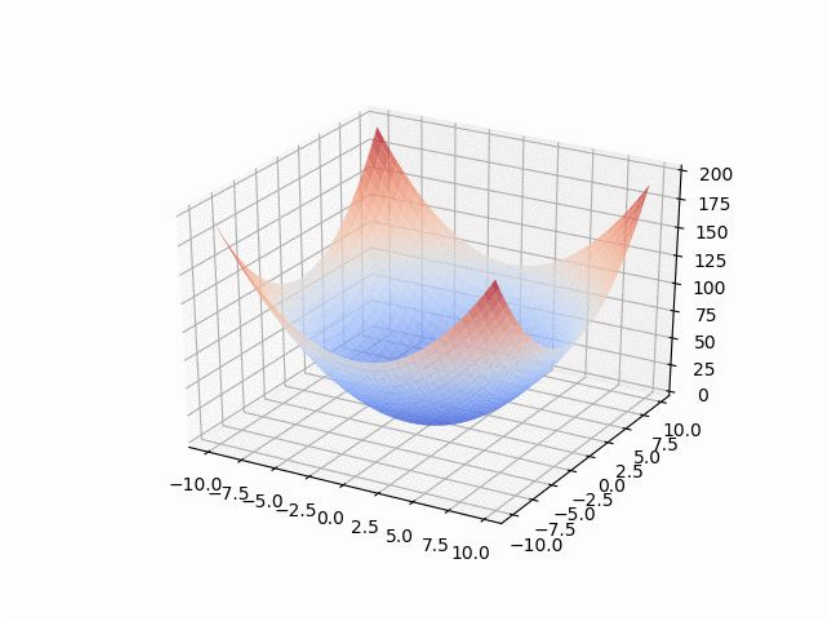
```
if r < e^-(f(x_1)-f(x))/T:
```

Also denoted as $\Delta \Rightarrow \Delta = f(x_1) - f(x)$

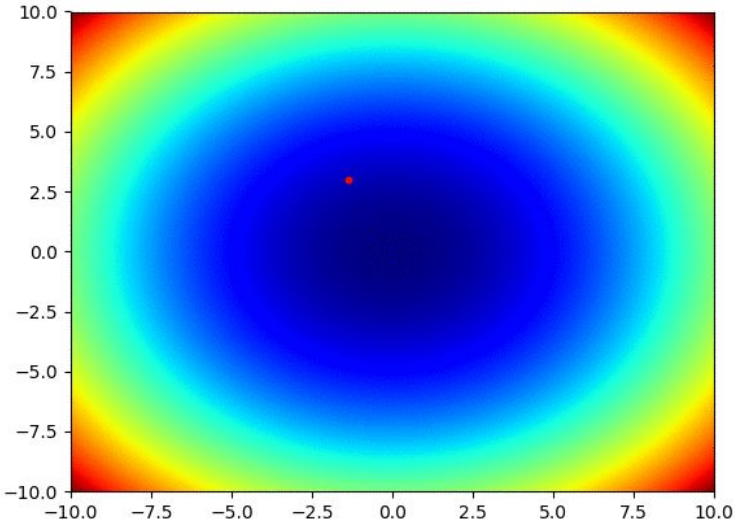
With decreasing value of T the probability to accept the worse solution decrease

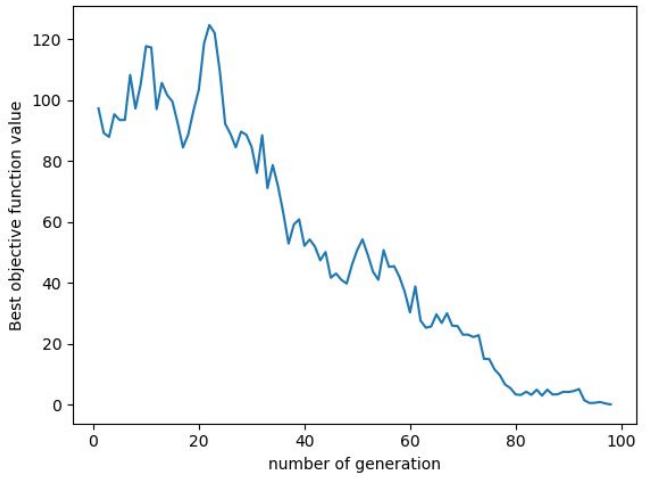
Simulated Annealing – Behaviour

- Worse solutions are accepted at the beginning of the algorithm
- At the end of algorithm, same behavior as Hill Climbing



Sphere function

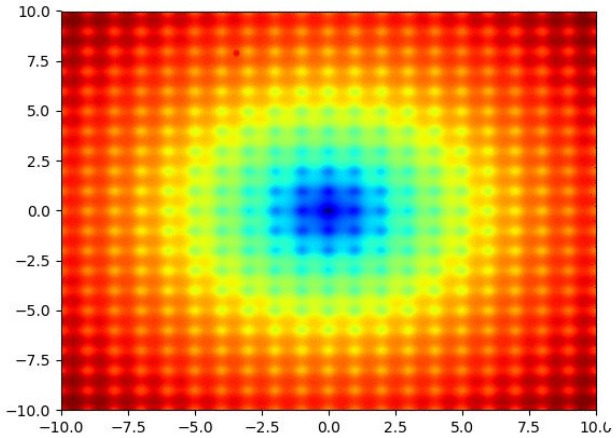


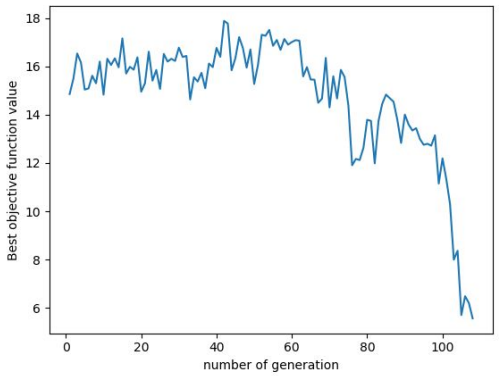


Simulated Annealing – Behaviour

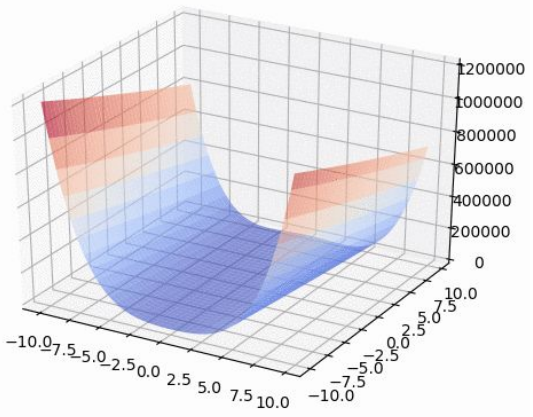
- Worse solutions are accepted at the beginning of the algorithm
- At the end of algorithm, same behavior as Hill Climbing

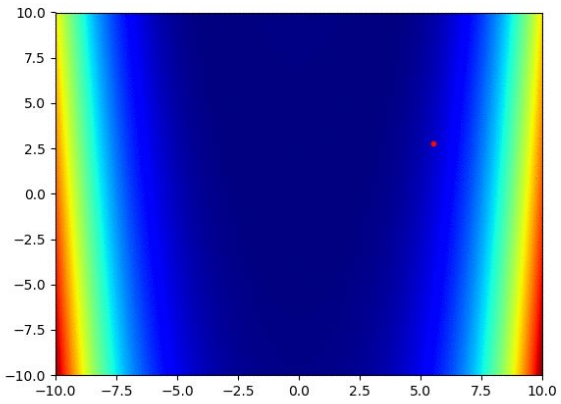
Ackley function





Rosenbrock function





Task

- Implement Simulated annealing algorithm
- Visualize the process of search for the global optimum in 3-dimensional space or using heat maps. Use the test functions implemented for Task 1
- Figure 1 and 2 serve as the inspiration for your solution
  - You can choose one of these approaches or implement both of them
  - Sometimes, heat map is more useful for illustration of algorithm behaviour

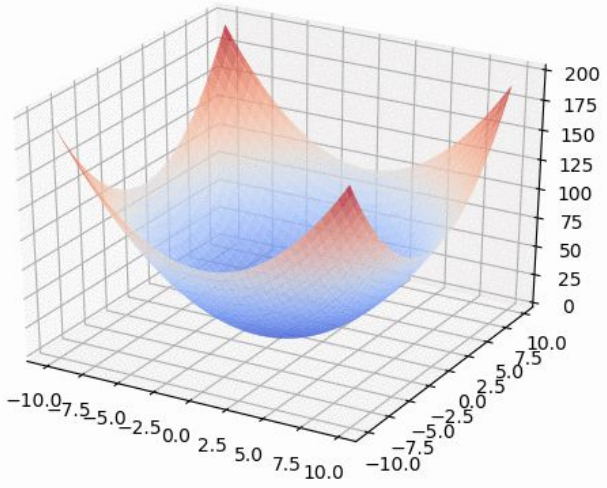
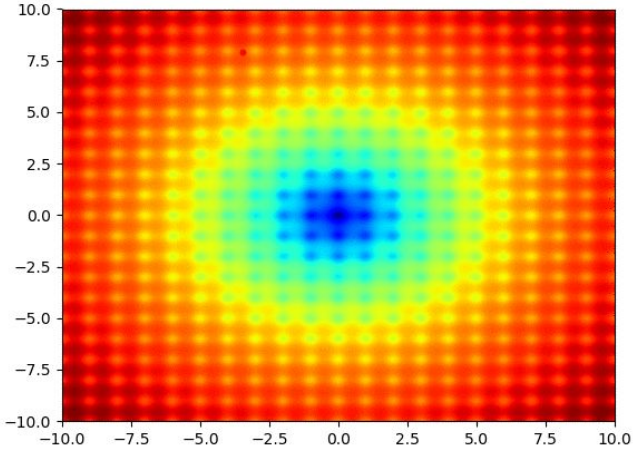


Figure 1: Simulated annealing used for Sphere function – 3D

Figure 2: Simulated annealing used for Ackley function – Heat map



Thank you for your attention

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