LAB-5 - Simulated Annealing Algorithm

Code:

```
import numpy as np
import math
import random

def objective_function(x):
    """Objective function to minimize: f(x) = x^2"""
    return x ** 2

def simulated_annealing(initial_state, initial_temp, cooling_rate, max_iterations):
    """Simulated Annealing algorithm to find the minimum of the objective function."""

    current_state = initial_state
    current_energy = objective_function(current_state)
    best_state = current_state
    best_energy = current_energy

    temp = initial_temp

    for iteration in range(max_iterations):
        # Generate a new candidate state by perturbing the current state
        candidate_state = current_state + random.uniform(-1, 1)
        candidate_energy = objective_function(candidate_state)

        # Calculate energy difference
        energy_diff = candidate_energy - current_energy

        # If the candidate state is better, or accepted with a certain probability
        if energy_diff < 0 or random.uniform(0, 1) < math.exp(-energy_diff / temp):
            current_state = candidate_state
            current_energy = candidate_energy

            # Update best state found
            if current_energy < best_energy:
                best_state = current_state
                best_energy = current_energy
```

```
        # Cool down the temperature
        temp *= cooling_rate

        # Print the current state and temperature for debugging
        print(f"Iteration {iteration + 1}: Current State = {current_state:.4f}, Current Energy =
{current_energy:.4f}, Temperature = {temp:.4f}")

    return best_state, best_energy

# Get user input for parameters
try:
    initial_state = float(input("Enter the initial state (starting point): "))
    initial_temp = float(input("Enter the initial temperature: "))
    cooling_rate = float(input("Enter the cooling rate (between 0 and 1): "))
    max_iterations = int(input("Enter the number of iterations: "))

    # Validate cooling rate
    if cooling_rate <= 0 or cooling_rate >= 1:
        raise ValueError("Cooling rate must be between 0 and 1.")

    # Execute the simulated annealing algorithm
    best_state, best_energy = simulated_annealing(initial_state, initial_temp, cooling_rate,
max_iterations)

    # Output the best state and energy found
    print(f"Best State: {best_state:.4f}, Best Energy: {best_energy:.4f}")

except ValueError as e:
    print(f"Invalid input: {e}")
```

Output:

```
Enter the initial state (starting point): 10
Enter the initial temperature: 12
Enter the cooling rate (between 0 and 1): 0.3
Enter the number of iterations: 25
Iteration 1: Current State = 10.0121, Current Energy = 100.2429, Temperature = 3.6000
Iteration 2: Current State = 10.0121, Current Energy = 100.2429, Temperature = 1.0800
Iteration 3: Current State = 10.0121, Current Energy = 100.2429, Temperature = 0.3240
Iteration 4: Current State = 9.2714, Current Energy = 85.9595, Temperature = 0.0972
Iteration 5: Current State = 9.2714, Current Energy = 85.9595, Temperature = 0.0292
Iteration 6: Current State = 9.2714, Current Energy = 85.9595, Temperature = 0.0087
Iteration 7: Current State = 9.2714, Current Energy = 85.9595, Temperature = 0.0026
Iteration 8: Current State = 9.2714, Current Energy = 85.9595, Temperature = 0.0008
Iteration 9: Current State = 9.2714, Current Energy = 85.9595, Temperature = 0.0002
Iteration 10: Current State = 9.2714, Current Energy = 85.9595, Temperature = 0.0001
Iteration 11: Current State = 8.9074, Current Energy = 79.3409, Temperature = 0.0000
Iteration 12: Current State = 8.9074, Current Energy = 79.3409, Temperature = 0.0000
Iteration 13: Current State = 8.9074, Current Energy = 79.3409, Temperature = 0.0000
Iteration 14: Current State = 8.2368, Current Energy = 67.8452, Temperature = 0.0000
Iteration 15: Current State = 7.5163, Current Energy = 56.4947, Temperature = 0.0000
Iteration 16: Current State = 7.5163, Current Energy = 56.4947, Temperature = 0.0000
Iteration 17: Current State = 7.0264, Current Energy = 49.3705, Temperature = 0.0000
Iteration 18: Current State = 7.0264, Current Energy = 49.3705, Temperature = 0.0000
Iteration 19: Current State = 6.6628, Current Energy = 44.3934, Temperature = 0.0000
Iteration 20: Current State = 6.5172, Current Energy = 42.4736, Temperature = 0.0000
Iteration 21: Current State = 6.4816, Current Energy = 42.0111, Temperature = 0.0000
Iteration 22: Current State = 6.4816, Current Energy = 42.0111, Temperature = 0.0000
Iteration 23: Current State = 6.4816, Current Energy = 42.0111, Temperature = 0.0000
Iteration 24: Current State = 6.4816, Current Energy = 42.0111, Temperature = 0.0000
Iteration 25: Current State = 6.4816, Current Energy = 42.0111, Temperature = 0.0000
Best State: 6.4816, Best Energy: 42.0111
```