VISVESVARAYA TECHNOLOGICAL UNIVERSITY

“JnanaSangama”, Belgaum -590014, Karnataka.

LAB RECORD

Bio Inspired Systems (23CS5BSBIS)

Submitted by

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1BM23CS083

in partial fulfillment for the award of the degree of

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in
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B.M.S. College of Engineering,

Bull Temple Road, Bangalore 560019

(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled " Bio Inspired Systems (23CS5BSBIS)" carried out by **D A Chethan (1BM23CS083),** who is bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements of the above mentioned subject and the work prescribed for the said degree.

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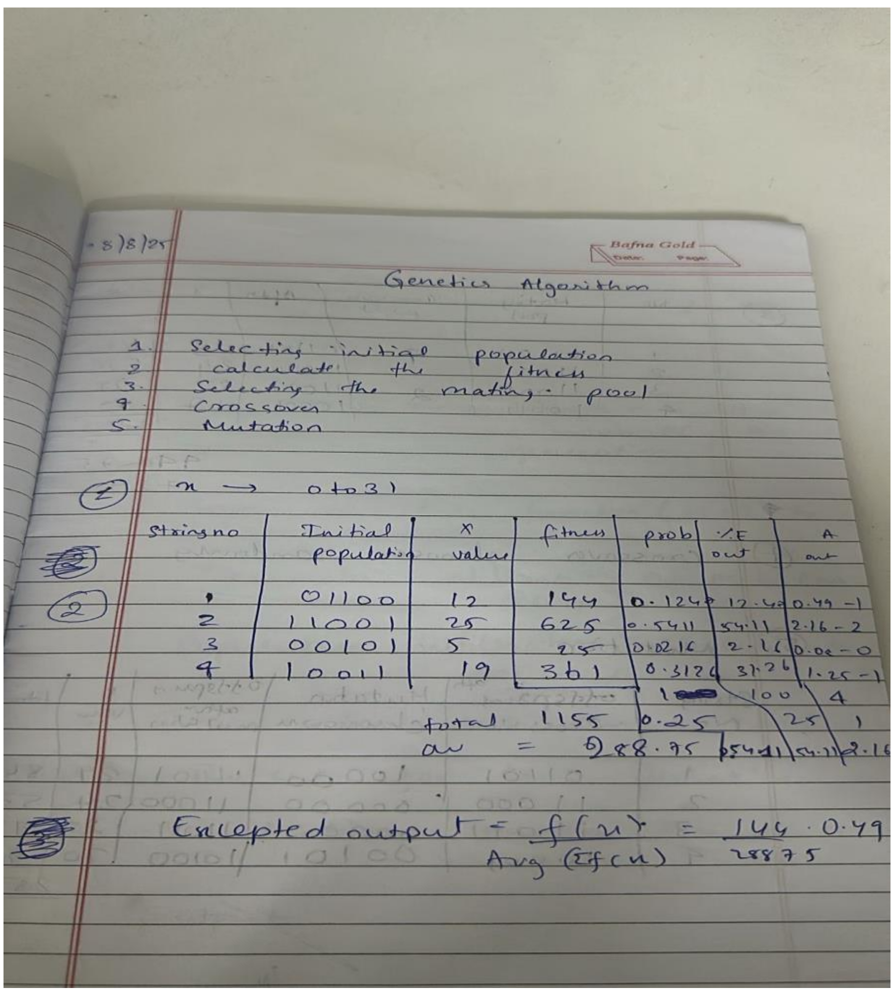
Github Link: https://github.com/DAChethan2485/1BM23CS083-BIS

Program 1

Genetic Algorithm for Optimization Problems:
Genetic Algorithms (GA) are inspired by the process of natural selection and genetics, where the fittest individuals are selected for reproduction to produce the next generation. GAs are widely used for solving optimization and search problems. Implement a Genetic Algorithm using Python to solve a basic optimization problem, such as finding the maximum value of a mathematical function.

Algorithm:



5/8/25

Genetics Algorithm

1. Selecting initial population
2. calculate the fitness
3. Selecting the mating pool
4. Crossover
5. Mutation

1. $x \rightarrow$ 0 to 31

2.

String no	Initial population	x value	fitness	prob	%E out	A out
1	01100	12	144	0.1247	12.47	0.49 - 1
2	11001	25	625	0.5411	54.11	2.16 - 2
3	00101	5	25	0.0216	2.16	0.08 - 0
4	10011	19	361	0.3126	31.26	1.25 - 1
				1	100	4
		total	1155	0.25	25	1
		avg =	288.75	0.5411	54.11	2.16

3. Excepted output = $\frac{f(x)}{Avg(\Sigma f(x))} = \frac{144}{288.75} \cdot 0.49$

(3)

S.No	Mating pool	Crossover point	After	x	f(x)
1	01100	4	01101	13	169
2	11001		11000	24	576
3	11001	2	11011	27	729
4	10011		10001	17	289
					1763

440.75

729.

(4) crossover choosen randomly

(5) Mutation

String No	offspring after crossover	Mutation chromosom	offspring after mutation	x value	f
1	01101	10000	11101	29	8
2	11000	00000	11000	24	5
3	11011	00000	11011	27	7
4	10001	00101	10100	20	
					28

28/8/2025

Code:

```
import random import numpy
as np import matplotlib.pyplot
as plt

def fitness_function(x):
    return x * np.sin(10 * np.pi * x) + 1.0

POP_SIZE = 30
GENES = 16
MUTATION_RATE = 0.01
CROSSOVER_RATE = 0.7
GENERATIONS = 100

def generate_individual():
    return ''.join(random.choice('01') for _ in range(GENES))

def decode(individual):
    return int(individual, 2) / (2**GENES - 1)

def evaluate_population(population):
    return [fitness_function(decode(ind)) for ind in population]

def select(population, fitnesses):
    total_fit = sum(fitnesses)
if total_fit == 0:
        return random.choices(population, k=2)     probabilities = [f
/ total_fit for f in fitnesses]     return random.choices(population,
weights=probabilities, k=2)

def crossover(parent1, parent2):     if random.random() <
CROSSOVER_RATE:         point = random.randint(1, GENES - 1)
return parent1[:point] + parent2[point:], parent2[:point] + parent1[point:]
return parent1, parent2

def mutate(individual):
return ''.join(
        bit if random.random() > MUTATION_RATE else random.choice('01')
for bit in individual
    )
```

```
def genetic_algorithm():
   population = [generate_individual() for _ in range(POP_SIZE)]
best_individual = population[0]     best_fitness =
fitness_function(decode(best_individual))     fitness_history = []

   for generation in range(GENERATIONS):
fitnesses = evaluate_population(population)
max_fit = max(fitnesses)        max_idx =
fitnesses.index(max_fit)        if max_fit >
best_fitness:            best_fitness = max_fit
best_individual = population[max_idx]
fitness_history.append(best_fitness)
new_population = []        while
len(new_population) < POP_SIZE:
         parent1, parent2 = select(population, fitnesses)
child1, child2 = crossover(parent1, parent2)
child1 = mutate(child1)            child2 =
mutate(child2)
new_population.extend([child1, child2])
population = new_population[:POP_SIZE]

   best_x = decode(best_individual)
   return best_x, best_fitness, fitness_history

best_x, best_fitness, history = genetic_algorithm()

print(f"Best solution found: x = {best_x:.5f}, f(x) = {best_fitness:.5f}") plt.plot(history)
plt.title("Fitness over Generations") plt.xlabel("Generation") plt.ylabel("Best Fitness") plt.grid(True)
plt.show()

import random

POP_SIZE = 100
NUM_CITIES = 20
GENERATIONS = 5
MUTATION_RATE = 5 / 100
CROSSOVER_RATE = 80 / 100

def generate_distance_matrix(num_cities):
   distance_matrix = [[0 if i == j else random.randint(10, 100) for j in range(num_cities)] for i in
range(num_cities)]     for i in range(num_cities):        for j in range(i + 1, num_cities):
         distance_matrix[j][i] = distance_matrix[i][j]
return distance_matrix
```

```
DISTANCE_MATRIX = generate_distance_matrix(NUM_CITIES)

class Individual:
def __init__(self):
        self.genome = random.sample(range(NUM_CITIES), NUM_CITIES)
self.fitness = self.calculate_fitness()

    def calculate_fitness(self):
        total_distance = 0         for i in
range(NUM_CITIES - 1):
            total_distance += DISTANCE_MATRIX[self.genome[i]][self.genome[i + 1]]
total_distance += DISTANCE_MATRIX[self.genome[NUM_CITIES - 1]][self.genome[0]]
self.fitness = 1 / total_distance         return self.fitness

    def mutate(self):         if random.random() <
MUTATION_RATE:
            i, j = random.sample(range(NUM_CITIES), 2)
self.genome[i], self.genome[j] = self.genome[j], self.genome[i]
self.fitness = self.calculate_fitness()

    @staticmethod     def
crossover(parent1, parent2):
start, end =
sorted(random.sample(range(NU
M_CITIES), 2))
child1_genome = [-1] *
NUM_CITIES
child2_genome = [-1] *
NUM_CITIES
child1_genome[start:end] =
parent1.genome[start:end]
child2_genome[start:end] =
parent2.genome[start:end]
fill_parent1 = [city for city in
parent2.genome if city not in
child1_genome]         fill_parent2
= [city for city in parent1.genome
if city not in child2_genome]
for i in range(NUM_CITIES):
if child1_genome[i] == -1:
                child1_genome[i] = fill_parent1.pop(0)
if child2_genome[i] == -1:
                child2_genome[i] = fill_parent2.pop(0)
child1 = Individual()         child1.genome =
```

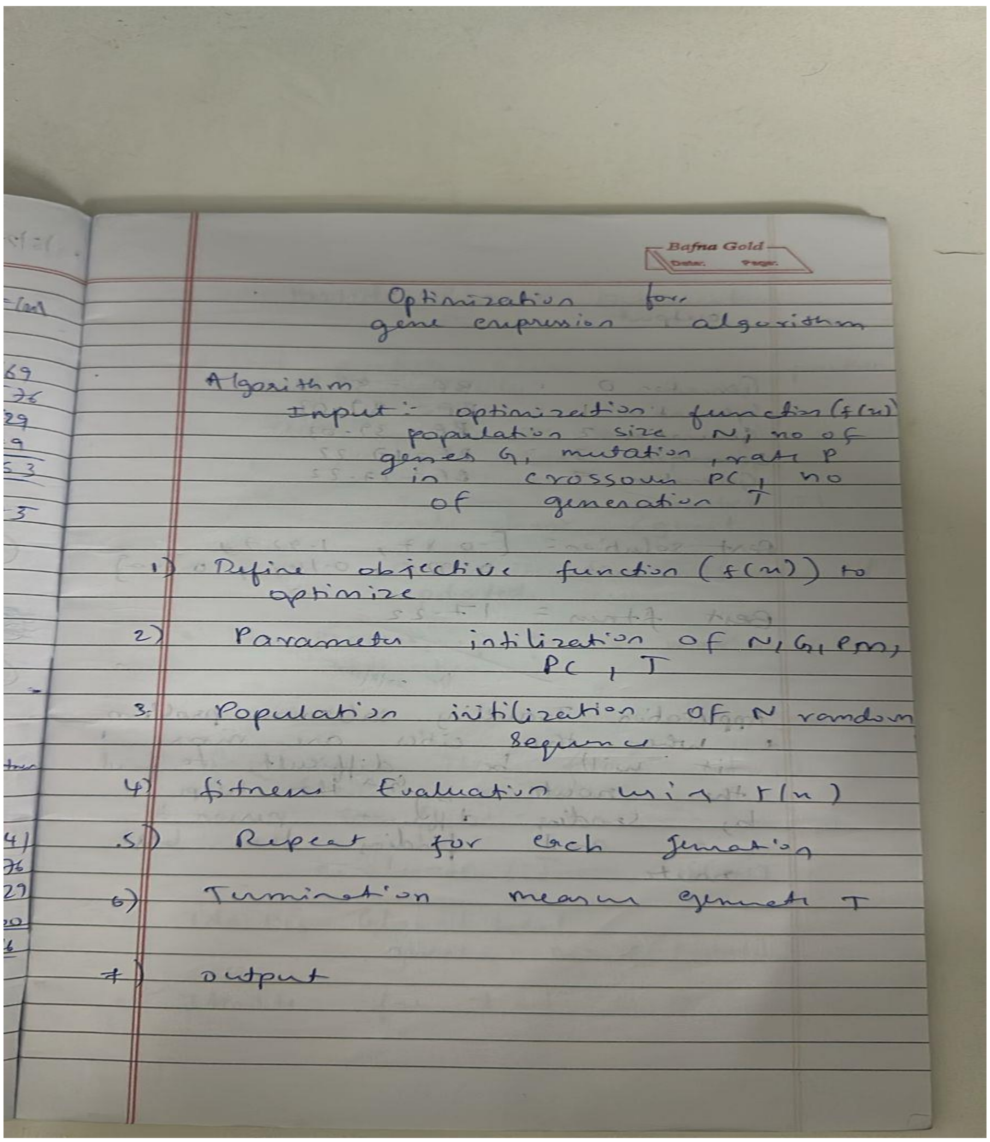
```
child1_genome        child1.fitness =
child1.calculate_fitness()        child2 =
Individual()        child2.genome =
child2_genome        child2.fitness =
child2.calculate_fitness()        return child1,
child2

def selection(population):
    total_fitness = sum(individual.fitness for individual in population)
pick = random.uniform(0, total_fitness)
    current = 0     for individual in
population:        current +=
individual.fitness        if current
> pick:            return individual
    return population[-1]

def initialize_population():
    return [Individual() for _ in range(POP_SIZE)]

def best_individual(population):
    return min(population, key=lambda individual: 1 / individual.fitness)

def main():
    population = initialize_population()     for
generation in range(GENERATIONS):
        population.sort(key=lambda individual: individual.fitness, reverse=True)
print(f"Generation {generation}: Best fitness = {population[0].fitness}, Distance =
{1/population[0].fitness}")        new_population =
[population[0], population[1]]        while
len(new_population) < POP_SIZE:
            parent1 = selection(population)
parent2 = selection(population)            if
random.random() < CROSSOVER_RATE:
child1, child2 = Individual.crossover(parent1,
parent2)            else:
                child1, child2 = parent1, parent2
child1.mutate()            child2.mutate()
new_population.append(child1)            if
len(new_population) < POP_SIZE:
new_population.append(child2)
population = new_population     best_solution
= best_individual(population)     print("\nBest
solution found:")     print(f"Tour:
{best_solution.genome}")
```

```
    print(f"Distance: {1 / best_solution.fitness}")

if __name__ == "__main__":
main()
```

<u>Program 2</u>

Optimization via Gene Expression Algorithms:
Gene Expression Algorithms (GEA) are inspired by the biological process of gene expression in living organisms. This process involves the translation of genetic information encoded in DNA into functional proteins. In GEA, solutions to optimization problems are encoded in a manner similar to genetic sequences. The algorithm evolves these solutions through selection, crossover, mutation, and gene expression to find optimal or near-optimal solutions. GEA is effective for solving complex optimization problems in various domains, including engineering, data analysis, and machine learning.

Algorithm:


Optimization for
gene expression algorithm

Algorithm
Input:- optimization function (f(x))
population size N, no of
genes G, mutation rate P
in crossover PC, no
of generation T

1) Define objective function (f(x)) to
optimize

2) Parameter intilization of N, G, Pm,
PC, T

3. Population intilization of N random
sequence

4) fitness Evaluation using f(x)

5) Repeat for each generation

6) Termination measure generate T

7) output

output

Generation 0 : BF = 59.73
Generation 1 : BF = 39.03
Generation 2 : BF = 39.03
Generation 3 : BF = 17.22
Generation 4 : BF = 17.22

Best solution = [-0.87, 1.927, 0.026, 0.144, 0.847]

Best fitness = 17.22

28/8/2025

Application Traveling salesman problem
* when the cities are more it will be difficult to find the route by G.A ~~this~~ helps by sending different person to it and finding the best route.

Code:

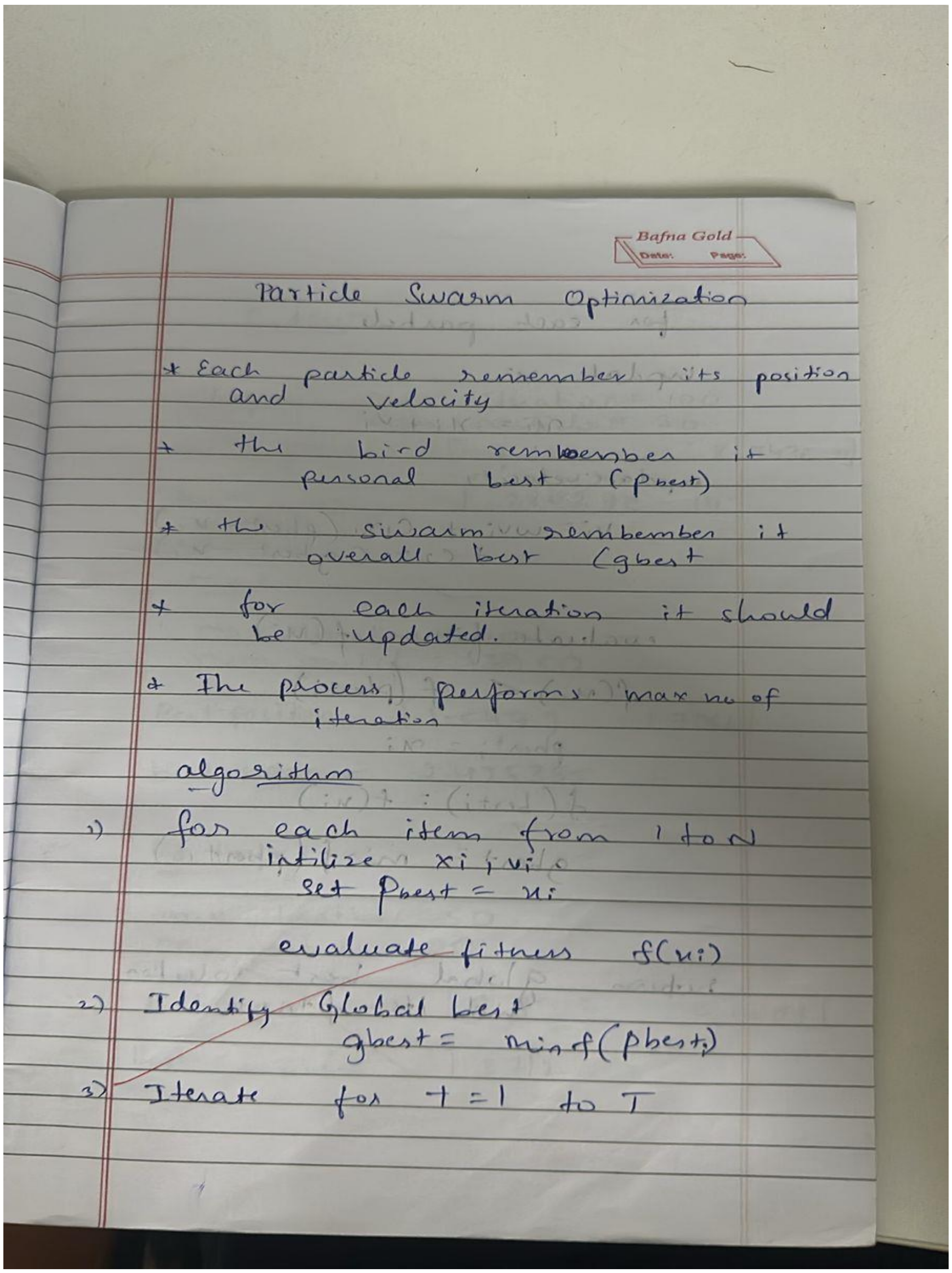
```
import random

POP_SIZE = 20
GENES = 5
GENERATIONS = 5
MUTATION_RATE = 0.1
CROSSOVER_RATE = 0.7

def fitness_function(treatment_plan):
   survival_rate = sum(treatment_plan) / len(treatment_plan)
return survival_rate

class Individual:
def __init__(self):
      self.genome = [random.randint(0, 10) for _ in range(GENES)]
self.fitness = self.calculate_fitness()

   def calculate_fitness(self):
      return fitness_function(self.genome)

   def mutate(self):       if random.random() <
MUTATION_RATE:            gene_idx =
random.randint(0, GENES - 1)
self.genome[gene_idx] = random.randint(0, 10)
self.fitness = self.calculate_fitness()

   @staticmethod     def
crossover(parent1, parent2):
      crossover_point = random.randint(1, GENES - 1)        child1_genome =
parent1.genome[:crossover_point] + parent2.genome[crossover_point:]        child2_genome =
parent2.genome[:crossover_point] + parent1.genome[crossover_point:]        child1 =
Individual()        child1.genome = child1_genome        child1.fitness =
child1.calculate_fitness()        child2 = Individual()        child2.genome = child2_genome
child2.fitness = child2.calculate_fitness()        return child1, child2

def selection(population):
   total_fitness = sum(individual.fitness for individual in population)
pick = random.uniform(0, total_fitness)     current = 0     for
individual in population:        current += individual.fitness        if
current > pick:            return individual
```

```
    return population[-1]

def initialize_population():
    return [Individual() for _ in range(POP_SIZE)]

def best_individual(population):
    return max(population, key=lambda individual: individual.fitness)

def main():
    population = initialize_population()     for
generation in range(GENERATIONS):
        population.sort(key=lambda individual: individual.fitness, reverse=True)
print(f"Generation {generation}: Best fitness = {population[0].fitness}, Genome =
{population[0].genome}")         new_population =
[population[0], population[1]]         while
len(new_population) < POP_SIZE:
            parent1 = selection(population)
parent2 = selection(population)             if
random.random() < CROSSOVER_RATE:
                child1, child2 = Individual.crossover(parent1, parent2)
else:
                child1, child2 = parent1, parent2             child1.mutate()
child2.mutate()             new_population.append(child1)             if
len(new_population) < POP_SIZE:
new_population.append(child2)         population = new_population     best
= best_individual(population)     print("\nBest treatment plan found:")
print(f"Genome: {best.genome}, Fitness (Survival Rate): {best.fitness}")

if __name__ == "__main__":
main()
```

Program 3

Particle Swarm Optimization for Function Optimization:
Particle Swarm Optimization (PSO) is inspired by the social behavior of birds flocking or fish schooling. PSO is used to find optimal solutions by iteratively improving a candidate solution with regard to a given measure of quality.

Algorithm:



Particle Swarm Optimization

* Each particle remember its position and velocity
* the bird remembember it personal best (pbest)
* the swarm rembember it overall best (gbest
* for each iteration it should be updated.
* The process performs max no of iteration

algorithm

1) for each item from 1 to N
   intilize x_i, v_i
   set $P_{best} = x_i$
   evaluate fitness $f(x_i)$
2) Identify Global best
   $g_{best} = \min f(pbest_i)$
3) Iterate for $t = 1$ to T

for each particle

update x_i

$$x_i = x_i + v_i$$

update velocity

$$v_i = wv_i + c_1 r_1 (pbest - x_i) + c_2 r_2 (gbest - x_i)$$

evaluate fitness $f(x_i)$

$f(x_i) \leq f(pbest_i)$

$pbest_i = x_i$

$f(best_i) = f(x_i)$

$gbest = \min f(pbest_i)$

return global best solution and its fitness

Output

try 1 max_iteration = 100
num_particle = 30

Best position : [-7.177e-08 8.747e-08]

Best score : 1.28027e-14

try 2

max_iteration = 100
num_particle = 50

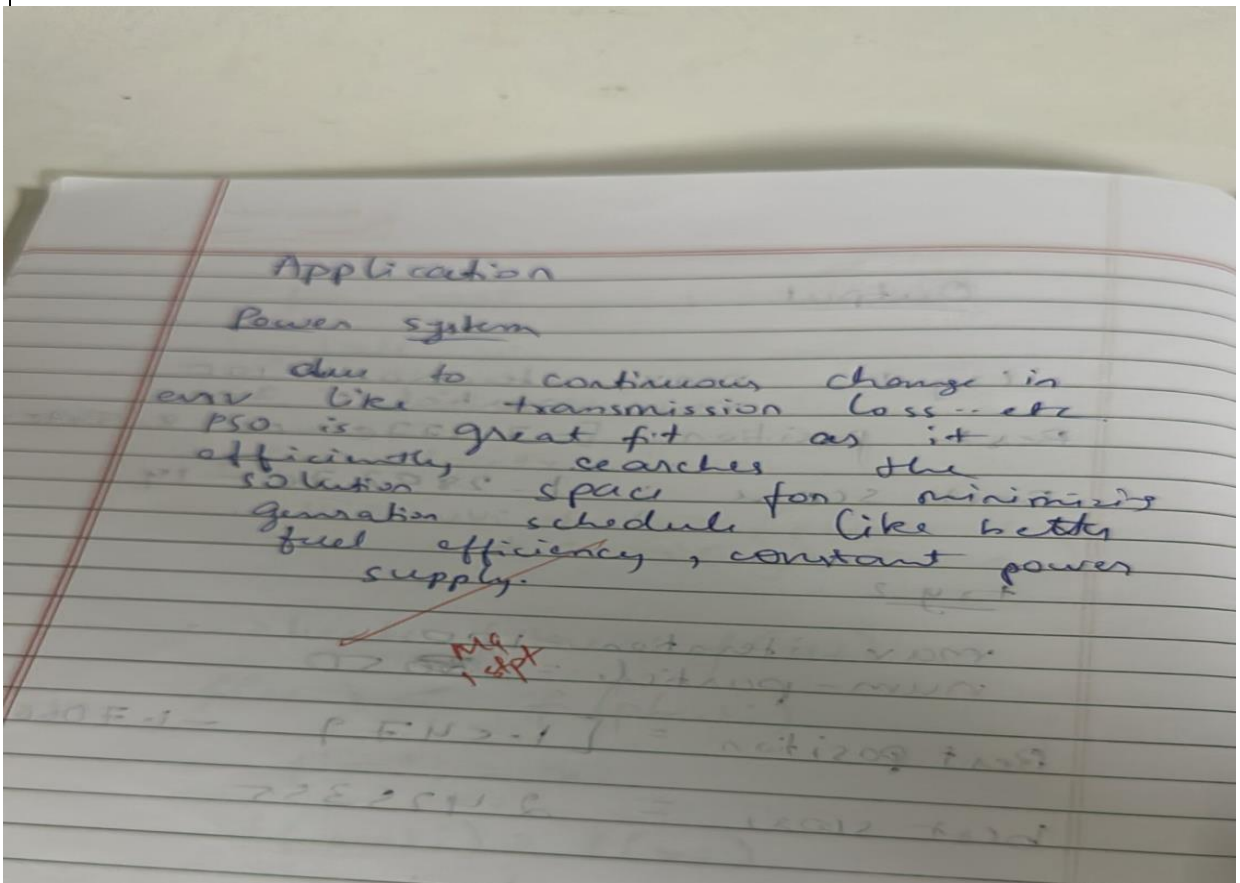
Best position = [1.5479 -1.7066]

best score = 2.425355

try-3

max iteration = 50
no_particle = 20

Best position = [0.0002 -0.0003]



Application
Power system
due to continuous change in env like transmission loss.. etc PSO is great fit as it efficiently searches the solution space for minimizing generation schedule like better fuel efficiency, constant power supply.

Code:

```
import random import math start = (0, 0)
goal = (10, 10) obstacles = [((3, 3), (5,
5)), ((6, 7), (8, 9))] def is_collision(p1,
p2):     for (bl, tr) in obstacles:
        x1, y1 = bl
        x2, y2 = tr         if (min(p1[0], p2[0]) < x2 and max(p1[0],
p2[0]) > x1 and             min(p1[1], p2[1]) < y2 and max(p1[1],
p2[1]) > y1):
            return True
return False def
path_length(path):
    length = 0     for i in
range(len(path)-1):         p1, p2
= path[i], path[i+1]         if
is_collision(p1, p2):
            return 10**6         length
+= math.dist(p1, p2)     return
length
```

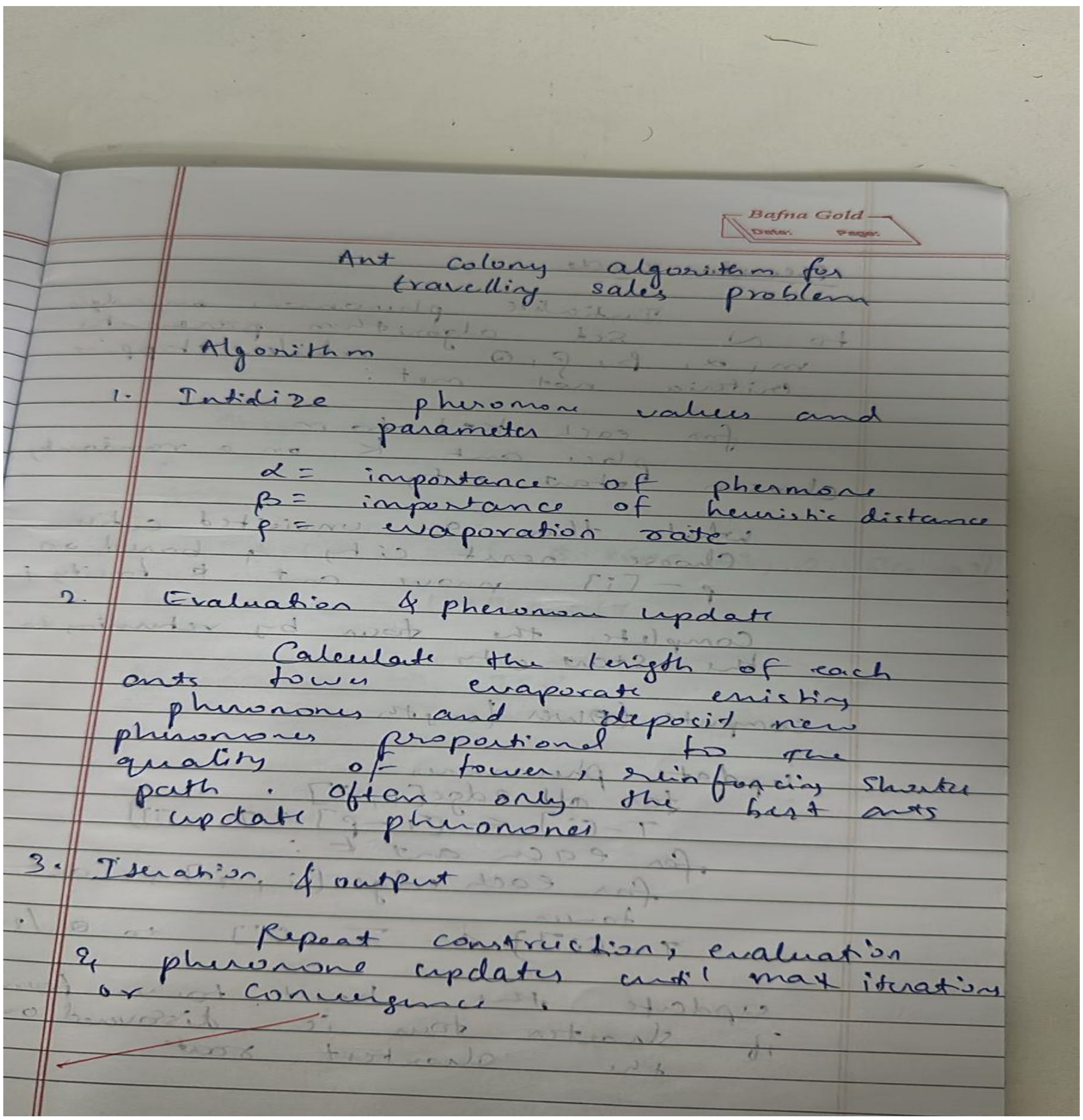
```
class Particle:     def __init__(self,
num_waypoints, bounds):
        self.position = [(random.uniform(bounds[0][0], bounds[0][1]),
random.uniform(bounds[1][0], bounds[1][1]))                         for _
in range(num_waypoints)]         self.velocity = [(0, 0) for _ in
range(num_waypoints)]
        self.best_position = list(self.position)
self.best_value = float("inf")     def
evaluate(self, func):         path = [start] +
self.position + [goal]         value =
func(path)         if value < self.best_value:
self.best_value = value
self.best_position = list(self.position)
return value

    def update_velocity(self, global_best, w, c1, c2):
        new_velocity = []         for i in
range(len(self.position)):             r1, r2 =
random.random(), random.random()
            vx = (w * self.velocity[i][0] +                 c1 * r1 *
(self.best_position[i][0] - self.position[i][0]) +                 c2 * r2 *
(global_best[i][0] - self.position[i][0]))
            vy = (w * self.velocity[i][1] +                 c1 * r1 *
(self.best_position[i][1] - self.position[i][1]) +                 c2 * r2 *
(global_best[i][1] - self.position[i][1]))
            new_velocity.append((vx, vy))
        self.velocity = new_velocity

    def update_position(self, bounds):
        new_position = []         for i in
range(len(self.position)):
            x = self.position[i][0] + self.velocity[i][0]
y = self.position[i][1] + self.velocity[i][1]             x
= max(bounds[0][0], min(x, bounds[0][1]))             y
= max(bounds[1][0], min(y, bounds[1][1]))
new_position.append((x, y))
        self.position = new_position

class PSO:
    def __init__(self, func, num_waypoints=3, bounds=[(0, 10), (0, 10)],
num_particles=20, max_iter=100, w=0.5, c1=1.5, c2=1.5):
        self.func = func
self.num_waypoints = num_waypoints
```

```
        self.bounds = bounds         self.swarm = [Particle(num_waypoints, bounds) for
_ in range(num_particles)]
        self.global_best_position = list(self.swarm[0].position)
self.global_best_value = float("inf")         self.max_iter =
max_iter         self.w, self.c1, self.c2 = w, c1, c2

    def run(self):         for _ in
range(self.max_iter):             for
particle in self.swarm:
                value = particle.evaluate(self.func)                 if value <
self.global_best_value:                     self.global_best_value =
value                     self.global_best_position =
list(particle.best_position)             for particle in self.swarm:
                particle.update_velocity(self.global_best_position, self.w, self.c1, self.c2)
particle.update_position(self.bounds)         return self.global_best_position,
self.global_best_value if __name__ == "__main__":
    pso = PSO(func=path_length, num_waypoints=3, max_iter=100)
    best_path, best_value = pso.run()
full_path = [start] + best_path + [goal]
print("Best Path Found:")     for p in
full_path:
        print(p)
    print("Total Path Length:", best_value")
```

Program 4

Ant Colony Optimization for the Traveling Salesman Problem:
The foraging behavior of ants has inspired the development of optimization algorithms that can solve complex problems such as the Traveling Salesman Problem (TSP). Ant Colony Optimization (ACO) simulates the way ants find the shortest path between food sources and their nest. Implement the ACO algorithm using Python to solve the TSP, where the objective is to find the shortest possible route that visits a list of cities and returns to the origin city.

Algorithm:



Bafna Gold
Date: Page:

Ant colony algorithm for travelling sale's problem

Algorithm

1. Initialize pheromone values and parameter

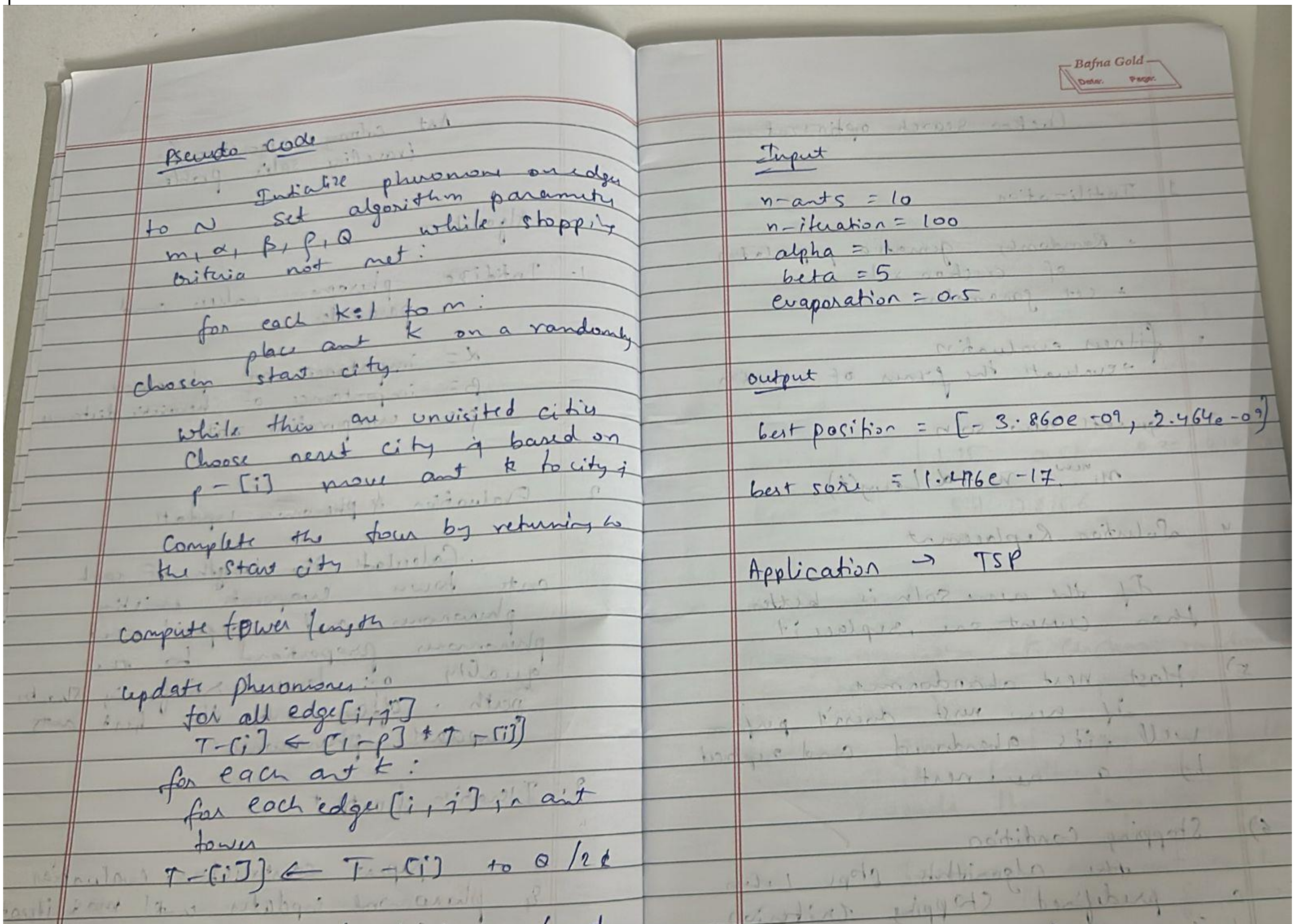
α = importance of phermone
β = importance of heuristic distance
ρ = evaporation rate

2. Evaluation & pheromone update

Calculate the length of each ants tour evaporate existing pheromones and deposit new pheromones proportional to the quality of tower, reinforcing shorter path. Often only the best ants update pheromones.

3. Iteration & output

Repeat construction, evaluation & pheromone updates until max iterations or convergence.


Pseudo code
Initialize pheromone on edges to N Set algorithm parameters m, α, β, ρ, Q while stopping criteria not met:

for each k=1 to m:
place ant k on a randomly chosen start city.

while there are unvisited cities
Choose next city j based on ρ-[i] move ant k to city j

Complete the tour by returning to the start city

compute tour length

update pheromones:
for all edge[i,j]
T-[i] ← [1-ρ] * T-[ij]
for each ant k:
for each edge [i,j] in ant tour
T-[ij] ← T-[i] to Q/Lk

Input
n-ants = 10
n-iteration = 100
alpha = 1
beta = 5
evaporation = 0.5

Output
best position = [-3.860e-09, 2.464e-09]
best score = 1.4476e-17

Application → TSP

Code:

```
import random
import numpy as np

def calculate_distance(city1, city2):
    return np.sqrt((city1[0] - city2[0])**2 + (city1[1] - city2[1])**2)

def ant_colony_optimization(cities, n_ants, n_best, n_iterations, decay, alpha=1, beta=5, Q=100):
    n_cities = len(cities)
    dist = np.zeros((n_cities, n_cities))
for i in range(n_cities):         for j in
range(n_cities):
            dist[i][j] = calculate_distance(cities[i], cities[j])
pheromone = np.ones((n_cities, n_cities)) * 0.1
```

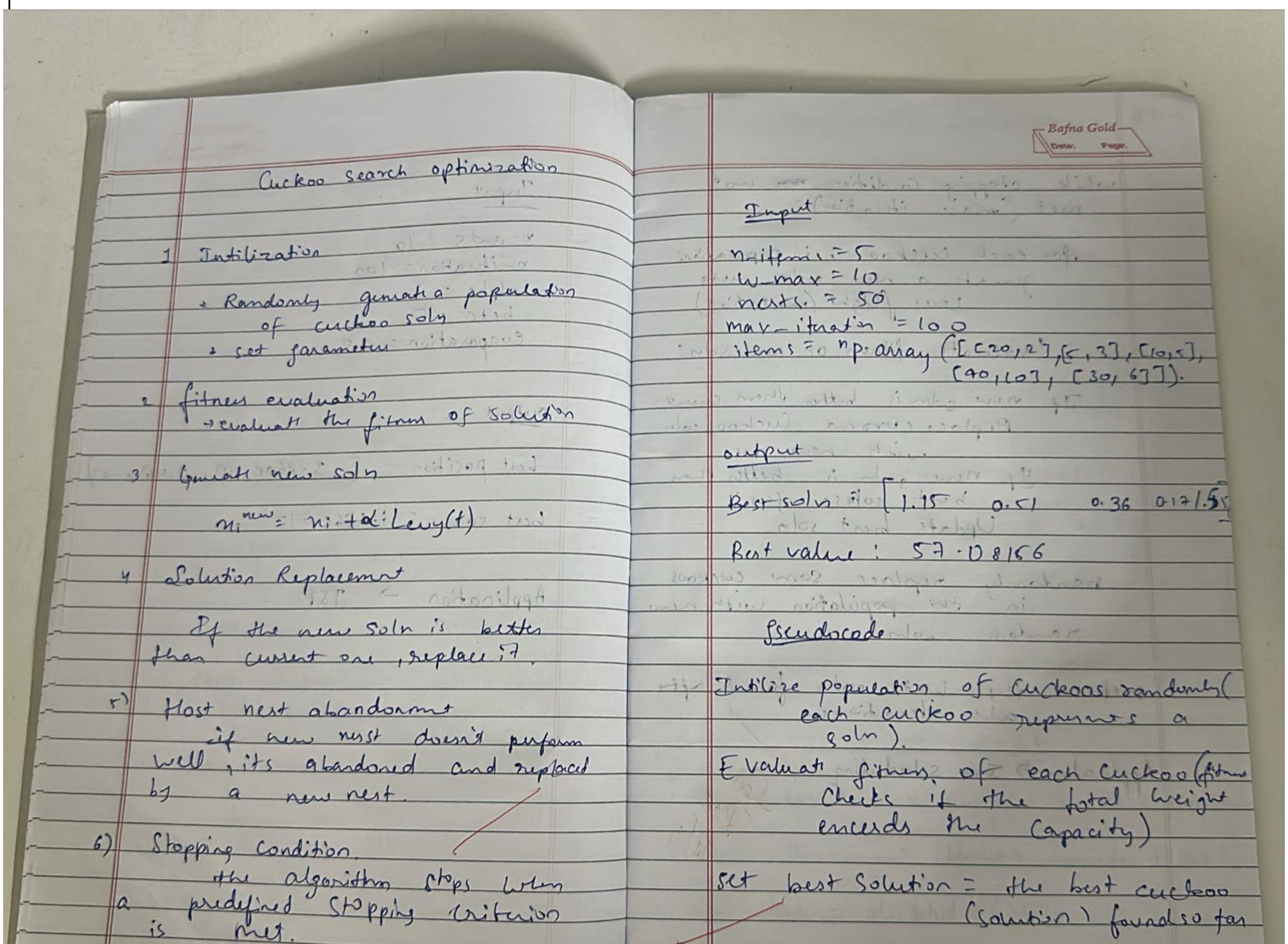
```
best_path = None     best_path_length = float('inf')
for _ in range(n_iterations):
        all_paths = []
all_lengths = []         for ant
in range(n_ants):
            path = []
            visited = [False] * n_cities              current_city = random.randint(0, n_cities - 1)
path.append(current_city)              visited[current_city] = True              for _ in
range(n_cities - 1):                 next_city = choose_next_city(current_city, visited,
pheromone, dist, alpha, beta)                 path.append(next_city)
visited[next_city] = True                 current_city = next_city              path.append(path[0])
path_length = calculate_path_length(path, dist)              all_paths.append(path)
all_lengths.append(path_length)              if path_length < best_path_length:
best_path_length = path_length
                best_path = path          pheromone *= (1 - decay)          for
path, length in zip(all_paths[:n_best], all_lengths[:n_best]):
            for i in range(len(path) - 1):
                pheromone[path[i]][path[i+1]] += Q / length
print(f"Best path length so far: {best_path_length}")     return
best_path, best_path_length

def choose_next_city(current_city, visited, pheromone, dist, alpha, beta):
    n_cities = len(pheromone)
probabilities = []     for i in
range(n_cities):         if not
visited[i]:
            pheromone_level = pheromone[current_city][i] ** alpha
distance_factor = (1.0 / dist[current_city][i]) ** beta
probabilities.append(pheromone_level * distance_factor)         else:
            probabilities.append(0)
total_prob = sum(probabilities)
    probabilities = [p / total_prob for p in probabilities]
    next_city = random.choices(range(n_cities), weights=probabilities)[0]
return next_city

def calculate_path_length(path, dist):
    length = 0     for i in
range(len(path) - 1):
        length += dist[path[i]][path[i+1]]
return length

if __name__ == "__main__":
    cities = [
(0, 0),
```

```
        (1, 2),
        (2, 4),
        (3, 1),
        (5, 0),
        (6, 3)
    ]
    n_ants = 10     n_best = 5     n_iterations = 100     decay = 0.95     best_path, best_path_length =
ant_colony_optimization(cities, n_ants, n_best, n_iterations, decay)     print("Best path found:",
best_path)
    print("Length of best path:", best_path_length)
```

Program 5

Cuckoo Search (CS):
Cuckoo Search (CS) is a nature-inspired optimization algorithm based on the brood parasitism of some cuckoo species. This behavior involves laying eggs in the nests of other birds, leading to the optimization of survival strategies. CS uses Lévy flights to generate new solutions, promoting global search capabilities and avoiding local minima. The algorithm is widely used for solving continuous optimization problems and has applications in various domains, including engineering design, machine learning, and data mining.

Algorithm:



Cuckoo search optimization

1 Intilization
+ Randomly generate a population of cuckoo soln
+ set parameters

2 fitness evaluation
→ evaluate the fitness of solution

3 Generate new soln
$x_i^{new} = x_i + \alpha \cdot Levy(t)$

4 Solution Replacement
If the new soln is better than current one, replace it.

5) Host nest abandonment
if new nest doesn't perform well, its abandoned and replaced by a new nest.

6) Stopping condition
the algorithm stops when a predefined stopping criterion is met.

Input
n_items = 5
W_max = 10
nests = 50
max_iteration = 100
items = np.array([[20,2],[5,3],[10,5], [40,10], [30,6]]).

output
Best soln: [1.15 0.51 0.36 0.17 1.55]
Best value : 57.08166

Pseudocode

Intilize population of cuckoos randomly (each cuckoo represents a soln).
Evaluate fitness of each cuckoo (fitness checks if the total weight exceeds the capacity)
set best solution = the best cuckoo (solution) found so far

while stopping condition ~~~~ not met (max iteration):

for each cuckoo i in population:
generate a new soln using
Levy flight (mutation)

Evaluate fitness of new soln:

If new soln is better than curr:
Replace current cuckoo soln
with new one.
If new soln is better than
best soln so far:
Update best soln

randomly replace some cuckoos
in the population with new
random soln

return the best soln found after
all iterations.

Application → Job scheduling

Seen
RCR
10/4

Code:

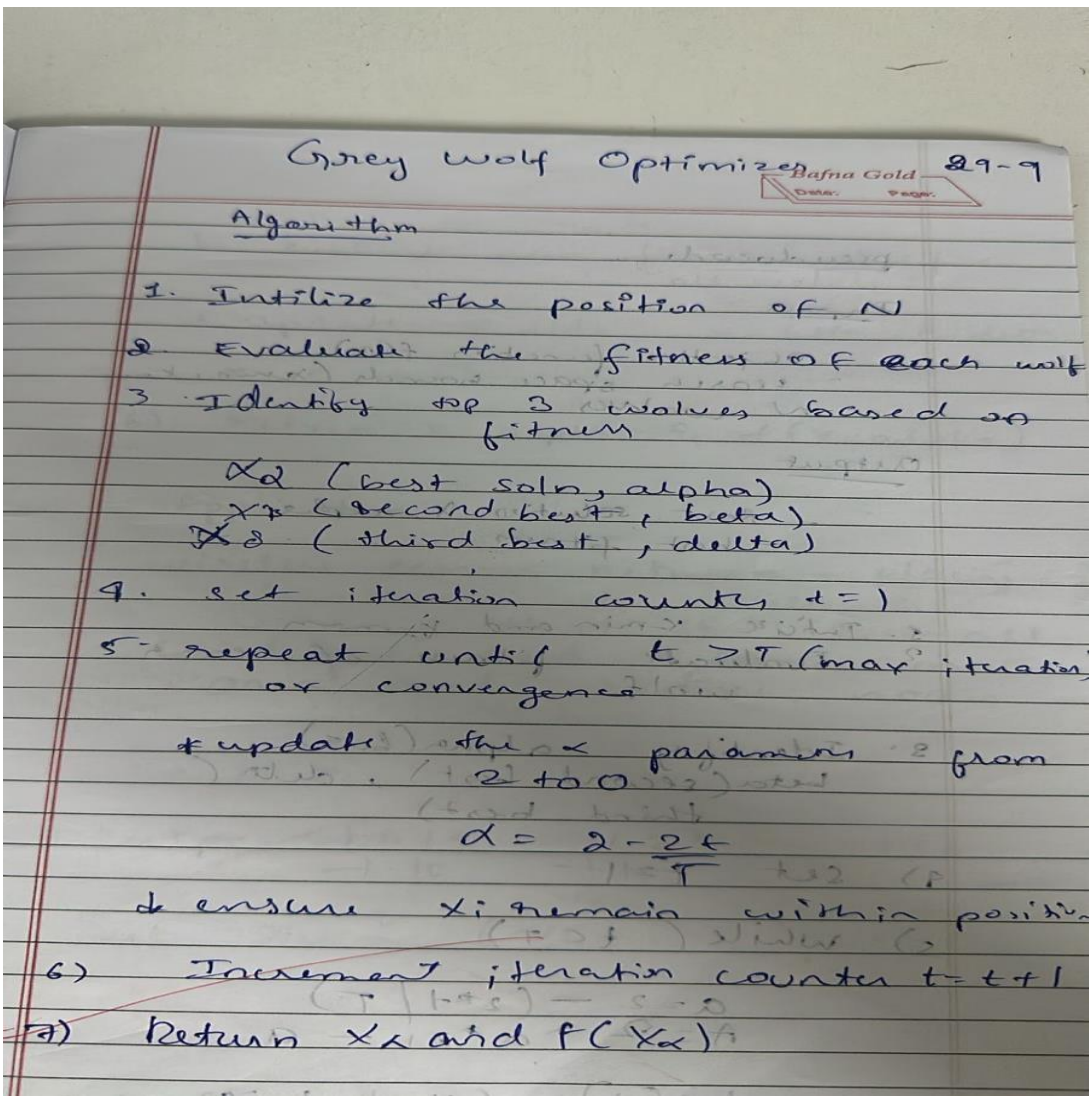
```
import random
import math

def distance(a, b):
    return math.sqrt((a[0] - b[0]) ** 2 + (a[1] - b[1]) ** 2)

def tour_length(tour, cities):
    total = 0.0     n =
len(tour)     for i in
range(n - 1):
        total += distance(cities[tour[i]], cities[tour[i + 1]])
total += distance(cities[tour[-1]], cities[tour[0]])     return
total

def levy_step_length(beta=1.5):
u = random.random()     step =
int(1 / (u ** (1 / beta)))     return
max(1, step)

def discrete_levy_flight(tour):
    new_tour = tour[:]     L
= levy_step_length()     n
= len(new_tour)     for _
in range(L):
        i, j = random.sample(range(n), 2)         new_tour[i],
new_tour[j] = new_tour[j], new_tour[i]     return
new_tour

def random_permutation(n):
perm = list(range(n))
random.shuffle(perm)     return
perm

def cuckoo_search_tsp(cities, n_nests=15, pa=0.25, max_iter=500, verbose=True):
    n_cities = len(cities)     nests = [random_permutation(n_cities)
for _ in range(n_nests)]     fitness = [tour_length(tour, cities) for
tour in nests]     best_index = min(range(n_nests), key=lambda i:
fitness[i])     best_tour = nests[best_index][:]     best_distance =
fitness[best_index]     for t in range(max_iter):
        j = random.randrange(n_nests)
cuckoo = discrete_levy_flight(nests[j])
```

```
cuckoo_fit = tour_length(cuckoo, cities)
k = random.randrange(n_nests)
        if cuckoo_fit < fitness[k]:
nests[k] = cuckoo
fitness[k] = cuckoo_fit         for i
in range(n_nests):             if
random.random() < pa:
                nests[i] = random_permutation(n_cities)
fitness[i] = tour_length(nests[i], cities)         best_index =
min(range(n_nests), key=lambda i: fitness[i])         if
fitness[best_index] < best_distance:             best_tour =
nests[best_index][:]             best_distance = fitness[best_index]
if verbose and (t % (max_iter // 10 + 1) == 0):
            print(f"Iteration {t}: Best distance so far = {best_distance:.3f}")
return best_tour, best_distance

if __name__ == "__main__":
    print("=== Cuckoo Search Algorithm for TSP ===")
n_cities = int(input("Enter number of cities: "))
cities = []     for i in range(n_cities):
        x = float(input(f"Enter x-coordinate of city {i}: "))         y =
float(input(f"Enter y-coordinate of city {i}: "))         cities.append((x,
y))     n_nests = int(input("Enter number of nests (population size): "))
pa = float(input("Enter discovery probability (0.0-1.0): "))     max_iter
= int(input("Enter maximum number of iterations: "))
print("\nRunning Cuckoo Search...")     best_tour, best_dist =
cuckoo_search_tsp(         cities, n_nests=n_nests, pa=pa,
max_iter=max_iter, verbose=True
    )
    print("\n=== Result ===")     print("Best
tour (city indices):", best_tour)
    print(f"Best distance: {best_dist:.3f}")
```

Program 6

Grey Wolf Optimizer (GWO):
The Grey Wolf Optimizer (GWO) algorithm is a swarm intelligence algorithm inspired by the social hierarchy and hunting behavior of grey wolves. It mimics the leadership structure of alpha, beta, delta, and omega wolves and their collaborative hunting strategies. The GWO algorithm uses these social hierarchies to model the optimization process, where the alpha wolves guide the search process while beta and delta wolves assist in refining the search direction. This algorithm is effective for continuous optimization problems and has applications in engineering, data analysis, and machine learning.

Algorithm:



Grey wolf Optimizer 29-9

Algorithm

1. Intilize the position of N
2. Evaluate the fitness of each wolf
3. Identify top 3 wolves based on fitness

X_α (best soln, alpha)
X_β (second best, beta)
X_δ (third best, delta)

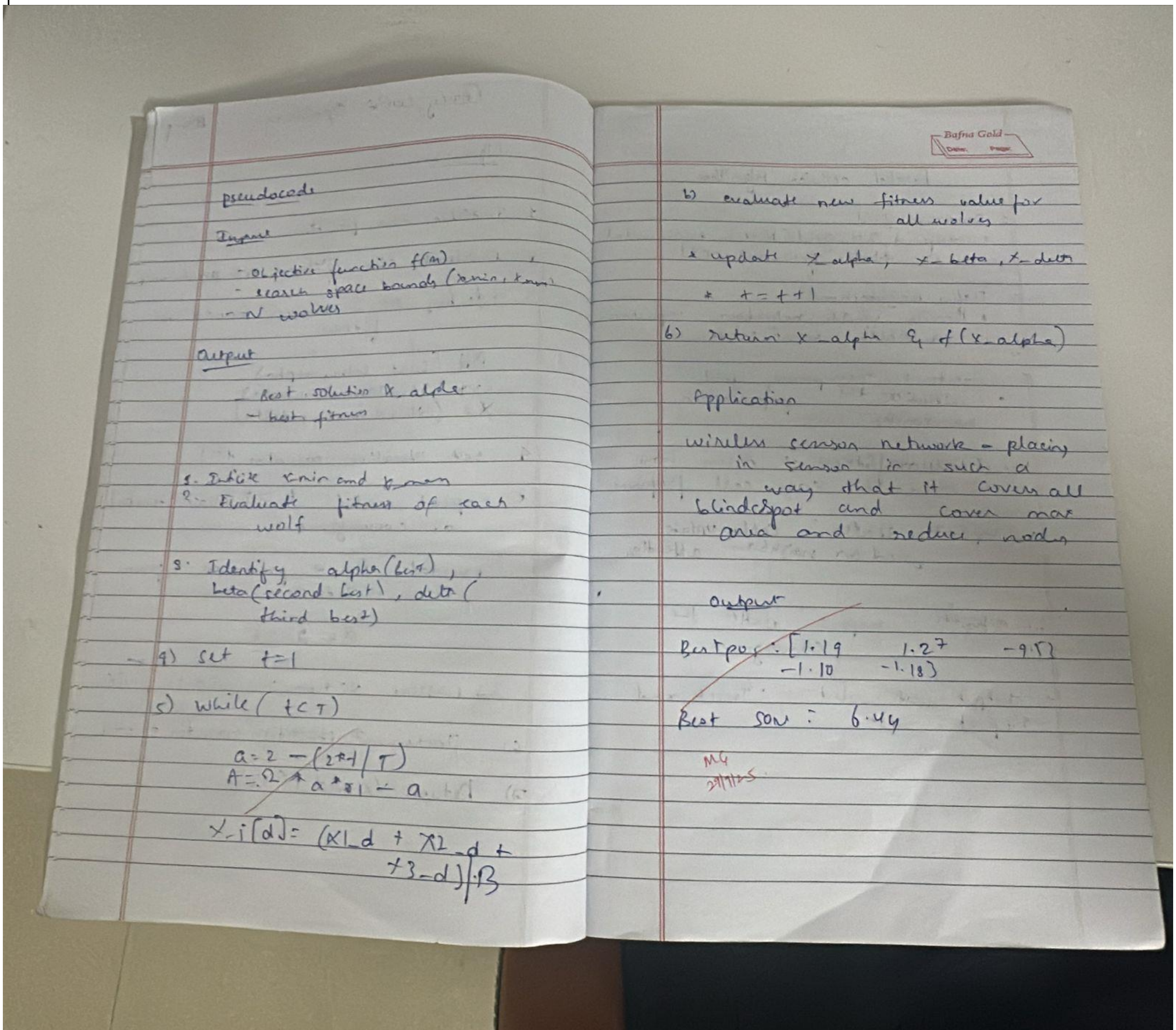
4. set iteration counter $t = 1$
5. repeat until $t \geq T$ (max iteration) or convergence

* update the α parameter from 2 to 0

$$\alpha = 2 - \frac{2t}{T}$$

* ensure X_i remain within position

6) Increment iteration counter $t = t+1$
7) Return X_α and $f(X_\alpha)$



pseudocode

Input

- objective function f(x)
- search space bounds (xmin, xmax)
- N wolves

Output

- Best solution X_alpha
- best fitness

1. Initialize xmin and xmax
2. Evaluate fitness of each wolf
3. Identify alpha(best), beta(second best), delta(third best)

4) set t=1

5) while (t<T)

a = 2 − (2*t / T)
A = 2 * a * r1 − a

X_i[d] = (X1_d + X2_d + X3_d) / 3

b) evaluate new fitness value for all wolves

* update X_alpha, X_beta, X_delta
* t = t+1

6) return X_alpha & f(X_alpha)

Application

wireless sensor network - placing in sensor in such a way that it covers all blindspot and cover max area and reduce nodes

Output

Best pos : [1.19 1.27 −9.51 −1.10 −1.18]

Best son : 6.44

MG
29/7/25

Code:

```
import random
import math

def kapur_entropy(thresholds, image):      thresholds =
sorted([int(round(t)) for t in thresholds])      thresholds =
[0] + thresholds + [256]      hist = [0]*256
total_pixels = 0      for row in image:          for pixel in
row:              hist[pixel] += 1              total_pixels += 1
prob = [h/total_pixels for h in hist]      total_entropy = 0
for i in range(len(thresholds)-1):
```

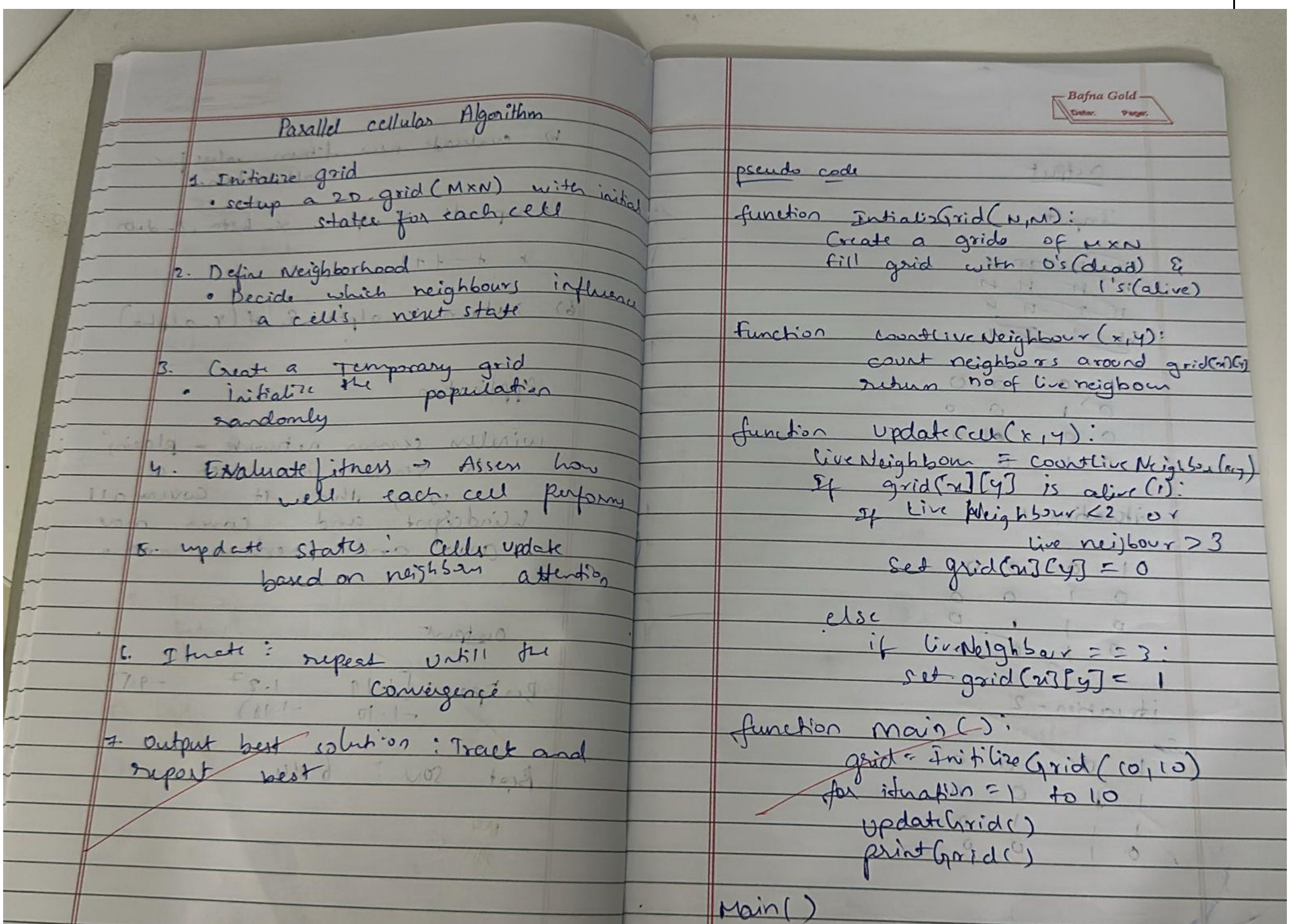
```
        start = thresholds[i]
end = thresholds[i+1]
        P = [p for p in prob[start:end] if p>0]
total_entropy += -sum([p*math.log(p) for p in P])
return -total_entropy

def GWO_image(image, D, N=10, MaxIter=50, lb=0, ub=255):
    wolves = [[random.uniform(lb, ub) for _ in range(D)] for _ in range(N)]
alpha_pos = [0]*D     beta_pos = [0]*D     delta_pos = [0]*D
alpha_score = float("inf")     beta_score = float("inf")     delta_score =
float("inf")     for t in range(MaxIter):         a = 2 - 2*t/MaxIter         for i
in range(N):
            fitness = kapur_entropy(wolves[i], image)
if fitness < alpha_score:
                delta_score, delta_pos = beta_score, beta_pos[:]
beta_score, beta_pos = alpha_score, alpha_pos[:]
alpha_score, alpha_pos = fitness, wolves[i][:]             elif
fitness < beta_score:
                delta_score, delta_pos = beta_score, beta_pos[:]
beta_score, beta_pos = fitness, wolves[i][:]             elif
fitness < delta_score:
                delta_score, delta_pos = fitness, wolves[i][:]
for i in range(N):             for d in range(D):
                r1, r2 = random.random(), random.random()
                A1 = 2*a*r1 - a; C1 = 2*r2
                r1, r2 = random.random(), random.random()
A2 = 2*a*r1 - a; C2 = 2*r2
                r1, r2 = random.random(), random.random()
                A3 = 2*a*r1 - a; C3 = 2*r2
                D_alpha = abs(C1*alpha_pos[d] - wolves[i][d])
                D_beta = abs(C2*beta_pos[d] - wolves[i][d])
                D_delta = abs(C3*delta_pos[d] - wolves[i][d])
                X1 = alpha_pos[d] - A1*D_alpha
                X2 = beta_pos[d] - A2*D_beta                 X3 =
delta_pos[d] - A3*D_delta                 wolves[i][d] = (X1 + X2
+ X3)/3                 if wolves[i][d] < lb: wolves[i][d] = lb
if wolves[i][d] > ub: wolves[i][d] = ub     return [int(round(x))
for x in alpha_pos def main():     filename = input("Enter PGM
image filename (grayscale): ")     image = []     with
open(filename, 'r') as f:
        lines = f.readlines()     lines = [l for l in
lines if not l.startswith('#')]     if
lines[0].strip() != 'P2':
        print("Only ASCII PGM (P2) supported.")
```

```
        return     idx = 2     while len(image) <
int(lines[1].split()[1]):         row =
list(map(int, lines[idx].split()))
        image.append(row)
idx += 1
    D = int(input("Enter number of thresholds: "))
    N = int(input("Enter number of wolves: "))     MaxIter =
int(input("Enter maximum iterations: "))
best_thresholds = GWO_image(image, D, N, MaxIter)
print("Best thresholds found:", best_thresholds)
thresholds = sorted(best_thresholds)     thresholds = [0] +
thresholds + [256]     segmented = [[0 for _ in row] for
row in image]     for i in range(len(thresholds)-1):         for
r in range(len(image)):             for c in
range(len(image[0])):                 if thresholds[i] <=
image[r][c] < thresholds[i+1]:
                    segmented[r][c] = int((i+1)*(255/(len(thresholds)-1)))
    out_file = "segmented.pgm"
with open(out_file, 'w') as f:
f.write("P2\n")
        f.write(f"{len(segmented[0])} {len(segmented)}\n")
        f.write("255\n")
        for row in segmented:
            f.write(' '.join(map(str,row)) + '\n')
    print(f"Segmented image saved as {out_file}")

if __name__ == "__main__":
main()
```

Program 7

Parallel Cellular Algorithms and Programs:
Parallel Cellular Algorithms are inspired by the functioning of biological cells that operate in a highly parallel and distributed manner. These algorithms leverage the principles of cellular automata and parallel computing to solve complex optimization problems efficiently. Each cell represents a potential solution and interacts with its neighbors to update its state based on predefined rules. This interaction models the diffusion of information across the cellular grid, enabling the algorithm to explore the search space effectively. Parallel Cellular Algorithms are particularly suitable for largescale optimization problems and can be implemented on parallel computing architectures for enhanced performance.

Algorithm:

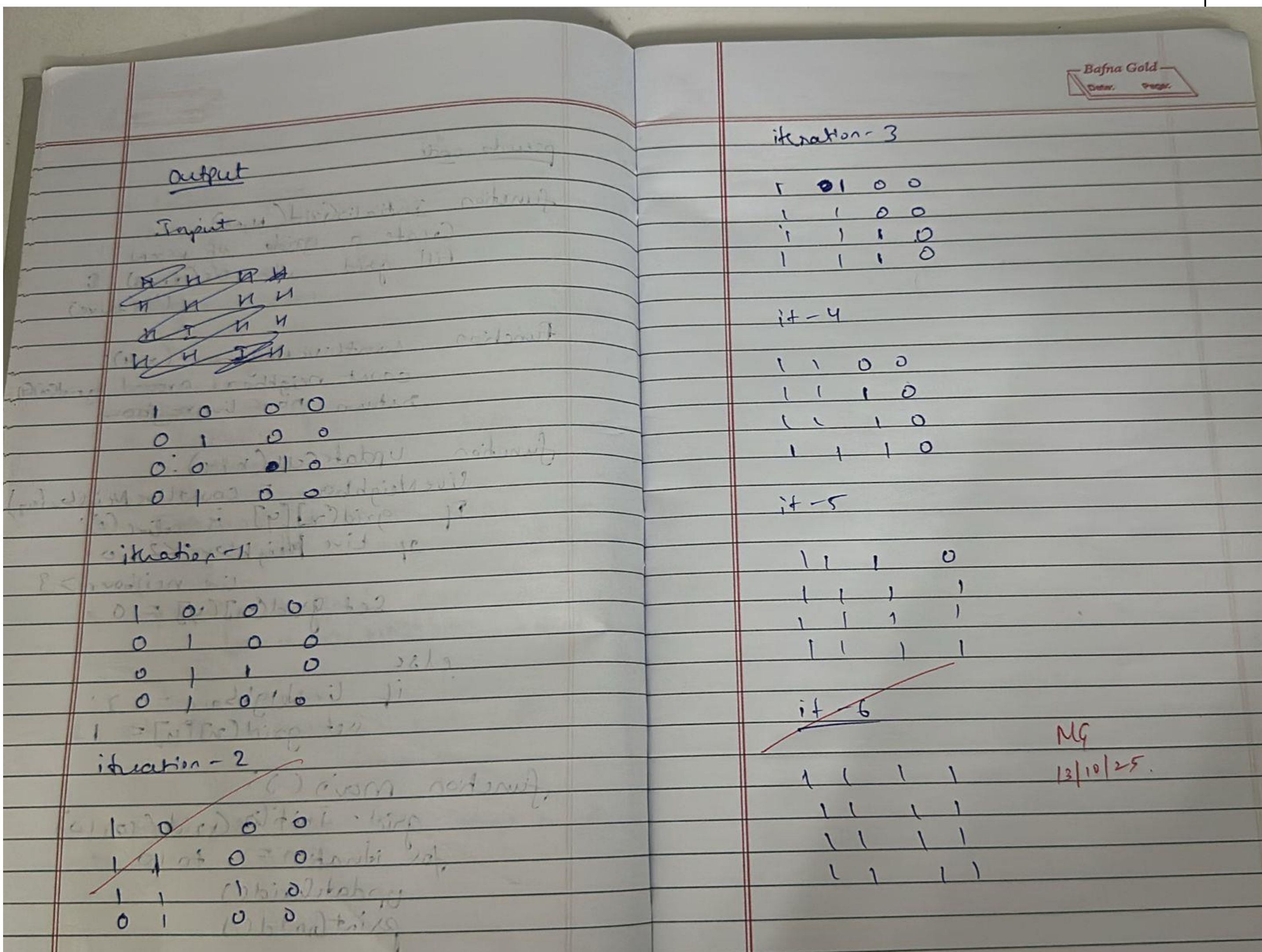


Parallel cellular Algorithm

1. Initialize grid
   • setup a 2D grid (MxN) with initial states for each cell
2. Define Neighborhood
   • Decide which neighbours influence a cell's next state
3. Create a Temporary grid
   • initialize the population randomly
4. Evaluate fitness → Assess how well each cell performs
5. update states : Cells update based on neighbour attention
6. Iterate : repeat until the convergence
7. Output best solution : Track and report best

pseudo code

```
function InitializeGrid(N,M):
    Create a grid of MxN
    fill grid with 0's(dead) &
                   1's(alive)

function countLiveNeighbour(x,y):
    count neighbours around grid[x][y]
    return no of live neighbour

function updateCell(x,y):
    liveNeighbour = countLiveNeighbour(x,y)
    If grid[x][y] is alive (1):
        If live Neighbour <2 or
           live neighbour >3
        Set grid[x][y] = 0
    else
        if liveNeighbour == 3:
            set grid[x][y] = 1

function main():
    grid = InitilizeGrid(10,10)
    for iteration =1 to 10
        updateGrid()
        printGrid()

Main()
```



Code:

```
import random

EMPTY = " "
TREE = "T"
BURNING = "F"

def get_neighbors(grid, i, j, neighborhood_type=8):
    rows = len(grid)     cols =
len(grid[0])     neighbors = []
if neighborhood_type == 4:
```

```
        directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]
else:
        directions = [
            (-1, -1), (-1, 0), (-1, 1),
            (0, -1),          (0, 1),
            (1, -1), (1, 0), (1, 1)
        ]
    for dx, dy in directions:         x, y = i
+ dx, j + dy         if 0 <= x < rows and 0
<= y < cols:
            neighbors.append((x, y))
return neighbors

def ForestFireModel(grid, num_iterations, prob_lightning, prob_tree_growth):
for _ in range(num_iterations):
        new_grid = [row[:] for row in grid]
for i in range(len(grid)):             for j in
range(len(grid[0])):
                state = grid[i][j]                neighbors =
get_neighbors(grid, i, j, 8)                 if state ==
BURNING:
                    new_grid[i][j] = EMPTY                elif state ==
TREE:                    if any(grid[x][y] == BURNING for x, y in
neighbors):
                        new_grid[i][j] = BURNING
elif random.random() < prob_lightning:
                        new_grid[i][j] = BURNING
elif state == EMPTY:                     if
random.random() < prob_tree_growth:
                        new_grid[i][j] = TREE
        grid = new_grid
print_grid(grid)
    return grid

def print_grid(grid):
for row in grid:
        print(" ".join(row))
    print("-" * (2 * len(grid[0]) - 1))

if __name__ == "__main__":
    rows = int(input("Enter number of rows: "))     cols = int(input("Enter
number of columns: "))     num_iterations = int(input("Enter number of
iterations: "))     prob_lightning = float(input("Enter probability of lightning
```

```
(0-1): "))     prob_tree_growth = float(input("Enter probability of tree growth
(0-1): "))     grid = []     for i in range(rows):
        row = []         for j
in range(cols):
            r = random.random()
if r < 0.6:
row.append(TREE)
elif r < 0.8:
                row.append(EMPTY)
else:
                row.append(BURNING)
        grid.append(row)
print("\nInitial Forest:")
print_grid(grid)
    print("Simulating fire spread...\n")     final_grid = ForestFireModel(grid,
num_iterations, prob_lightning, prob_tree_growth)     print("Final Forest State:")
    print_grid(final_grid)
```