VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka

LAB RECORD

Bio Inspired Systems (23CS5BSBIS)

Submitted by

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in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
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BullTempleRoad,Bangalore 560019
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Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled " Bio Inspired Systems (23CS5BSBIS)" carried out by Potnuru Ashrita ***(1BM23CS235),*** 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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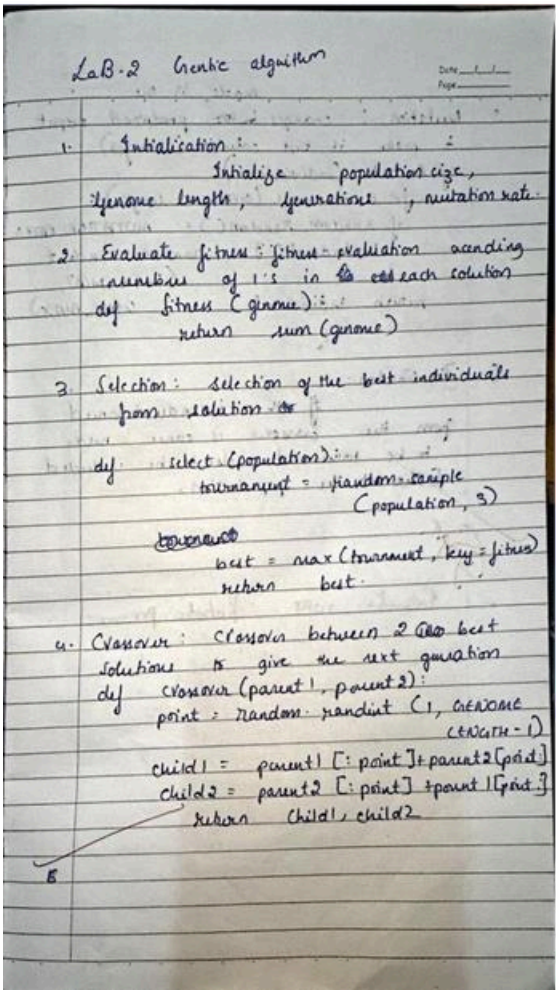
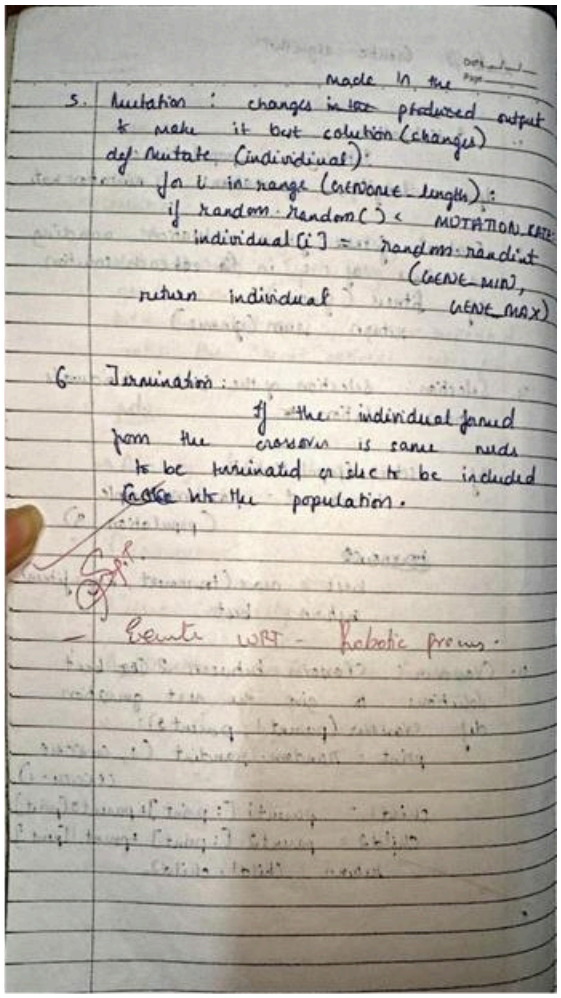
GITHUB LINK : - https://github.com/potnuruashrita/1bm23cs235-BIS.git

Program 1: Genetic algorithm using Engineering design

Algorithm:





Code:

```
import random
from typing import List, Dict, Tuple


TASK_DURATIONS: Dict[str, float] = {
    "Pick": 3.0,
    "Place": 2.5,
    "Screw": 4.0,
    "Inspect": 2.0,
    "Label": 1.5,
    "Pack": 3.5,
}
SETUP_PENALTY: Dict[Tuple[str, str], float] = {
    ("Pick", "Place"): 0.4, ("Place", "Screw"): 0.8, ("Screw", "Inspect"): 0.6,
    ("Inspect", "Label"): 0.3, ("Label", "Pack"): 0.7,

    ("Pick", "Screw"): 1.2, ("Pick", "Inspect"): 0.9, ("Pick", "Label"): 0.9, ("Pick", "Pack"): 1.1,

    ("Place", "Inspect"): 0.5, ("Place", "Label"): 0.5, ("Place", "Pack"): 0.9,
    ("Screw", "Place"): 1.0, ("Screw", "Label"): 0.7, ("Screw", "Pack"): 1.0,
```

```
    ("Inspect","Place"):0.7,("Inspect","Pack"):0.8, ("Inspect", "Screw"): 0.9,
    ("Label","Inspect"):0.6,("Label","Screw"):0.9, ("Label", "Place"): 0.8, ("Label", "Pick"): 1.0,
    ("Pack","Label"):0.6,("Pack","Inspect"):0.9,("Pack", "Screw"): 1.2, ("Pack", "Place"): 1.0,
}
defschedule_cost(order:List[str]) -> float:
    """Totaltime=sumofdurations+sequence-dependent penalties."""
    total= 0.0
    for i, task in enumerate(order):
        total+= TASK_DURATIONS[task]
        ifi>0:
            prev=order[i- 1]
            total+=SETUP_PENALTY.get((prev,task), 0.0)
    returntotal


definit_population(tasks:List[str],size:int)->List[List[str]]:
    pop = []
    for _ in range(size):
        chrom= tasks[:]
        random.shuffle(chrom)
        pop.append(chrom)
    returnpop

deftournament_select(pop:List[List[str]],k:int)-> List[str]:
    """k-waytournamentselection(minimization)."""
    cand = random.sample(pop, k)
    cand.sort(key=schedule_cost)
    return cand[0][:]

deforder_crossover(p1:List[str],p2:List[str])->Tuple[List[str], List[str]]:
    """Order crossover (OX) for permutations."""
    n = len(p1)
    a, b = sorted(random.sample(range(n), 2))
    def ox(parent_a, parent_b):
        child = [None]*n
        child[a:b+1] = parent_a[a:b+1]

        fill = [g for g in parent_b if g not in child]
        j = 0
        for i in range(n):
            if child[i] is None:
                child[i] = fill[j]
                j+=1
        return child
    return ox(p1, p2), ox(p2, p1)

defswap_mutation(ch:List[str],rate:float)->None:
    if random.random() < rate:
        i, j = random.sample(range(len(ch)), 2)
```

```
        ch[i], ch[j] = ch[j], ch[i]

    defevolve(
        tasks: List[str],
        pop_size: int = 80,
        generations: int = 300,
        tournament_k: int = 4,
        crossover_rate: float = 0.9,
        mutation_rate: float = 0.2,
        elitism: int = 2,
        verbose:                bool=                True
    ):
        pop=init_population(tasks,pop_size)
        best = min(pop, key=schedule_cost)
        best_score = schedule_cost(best)
        if verbose:
            print(f"Gen0|best={best_score:.3f} s | {best}")

        for g in range(1, generations + 1):
            new_pop = []
            pop_sorted=sorted(pop,key=schedule_cost)
            new_pop.extend([ch[:]forchinpop_sorted[:elitism]])
            #Createoffspring
            while len(new_pop) < pop_size:

                p1=tournament_select(pop,tournament_k)
                p2=tournament_select(pop,tournament_k)
                ifrandom.random()<crossover_rate:
                c1,c2=order_crossover(p1,p2)
                else:
                    c1, c2 = p1[:], p2[:]
                swap_mutation(c1,mutation_rate)
                swap_mutation(c2,mutation_rate)
                new_pop.append(c1)
                if len(new_pop) < pop_size:
                    new_pop.append(c2)

            pop = new_pop
            cur_best=min(pop,key=schedule_cost)
            cur_score=schedule_cost(cur_best)
            if cur_score < best_score:
                best,best_score=cur_best,cur_score

            ifverboseand(g%25==0org== generations):
                print(f"Gen{g}|best={best_score:.3f} s | {best}")

        return best, best_score

    if __name__ == "__main__":
```

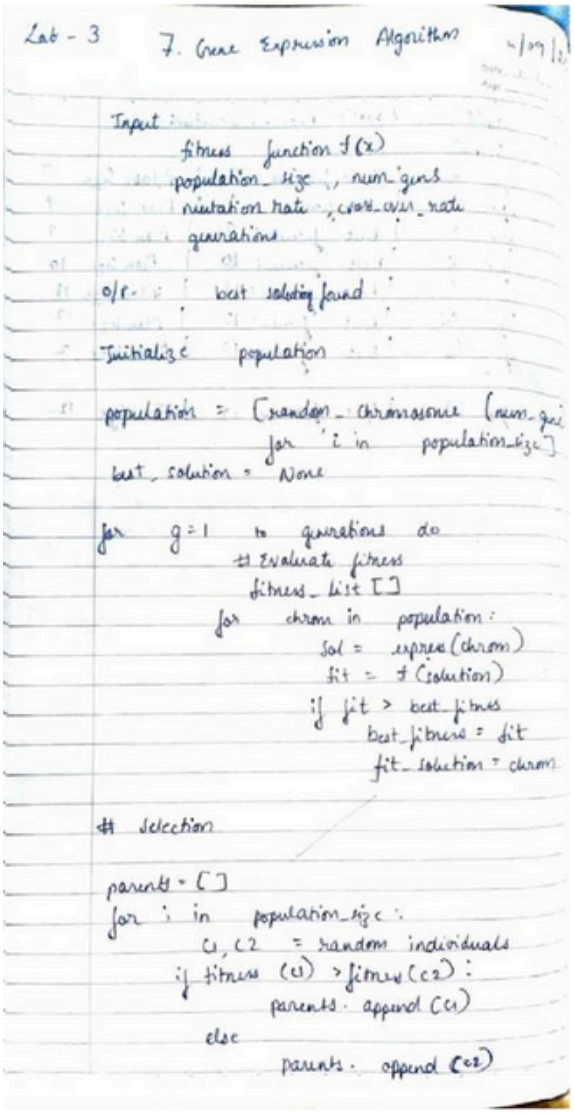
```
    random.seed(42)
    tasks = list(TASK_DURATIONS.keys())
    best_order, best_time = evolve(tasks, pop_size=120, generations=250, verbose=True)
    print("\nBest found sequence:")
    print(best_order)
print(f"Estimated total time: {best_time:.3f} s")
```

OUTPUT:

```
1BM23CS235-POTNURU ASHRITA
Gen 0 | best = 18.600 s | ['Pack', 'Pick', 'Place', 'Inspect', 'Label', 'Screw']
Gen 25 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 50 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 75 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 100 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 125 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 150 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 175 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 200 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 225 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 250 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']

Best found sequence:
['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Estimated total time: 18.400 s
```

Program 2: Genetic expression algorithm using Financial Forecasting

Algorithm:



Lab - 3 7. Gene Expression Algorithm

Input :
fitness function f(x)
population_size , num_gens
mutation_rate , cross_over_rate
generations

o/p : best solution found

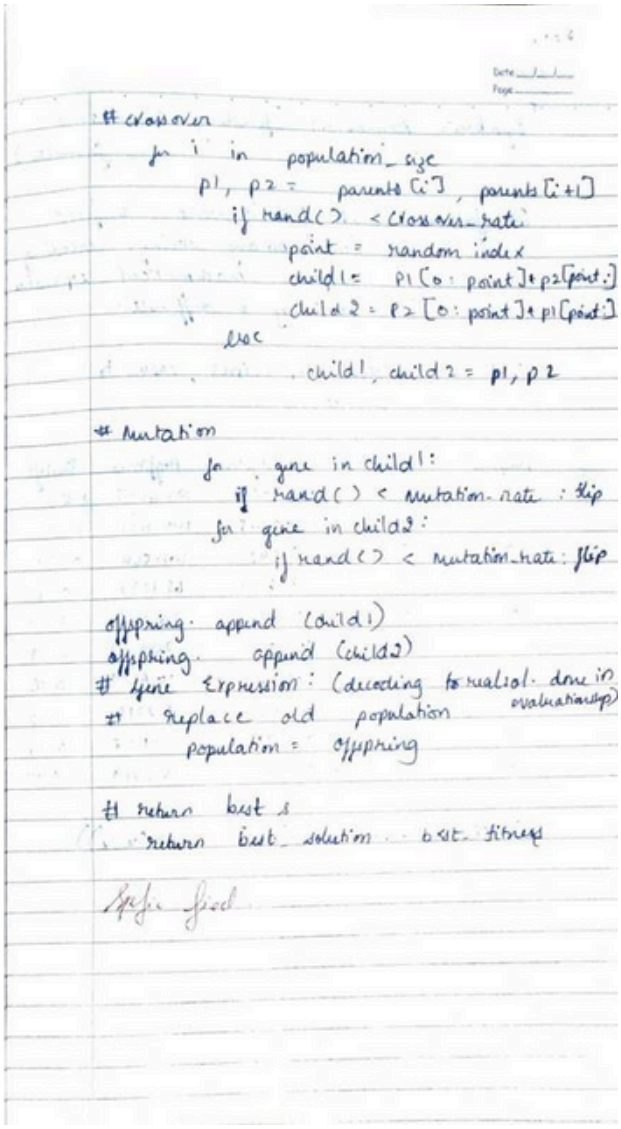
Initialize population

population = [random_chromosome (num_ge
for i in population_size]
best_solution = None

for g=1 to generations do
# Evaluate fitness
fitness_list []
for chrom in population:
sol = express(chrom)
fit = f(solution)
if fit > best_fitness
best_fitness = fit
fit_solution = chrom

Selection

parents = []
for i in population_size :
c1, c2 = random individuals
if fitness (c1) > fitness(c2) :
parents. append (c1)
else
parents. append (c2)



crossover
for i in population_size
p1, p2 = parents [i] , parents [i+1]
if rand() < cross_over_rate
point = random index
child1 = p1[0 : point] + p2[point:]
child 2 = p2 [0 : point] + p1[point:]
else
child1, child 2 = p1, p2

Mutation
for gene in child1 :
if rand() < mutation_rate : flip
for gene in child2 :
if rand() < mutation_rate : flip

offspring. append (child1)
offspring. append (child2)
# gene Expression : (decoding to realiol done in evaluation fn)
# replace old population
population = offspring

return best s
return best_solution, best_fitness

Specific find

Date __/__/____
Page _____

Symbolic Regression (finding mathematical formulas)

GA failure: GA fails it: works on fixed-length binary strings, encoding complex mathematical expressions directly is difficult.

GEP: evolves expressions, easier to encode.

Progress	Generation	Best fitness	Avg fitness	Time
1	0	168.9403	192.6539	0.36
2	1	121.5268	144.2123	0.33
3	2	79.2453	101.564	0.29
4	3	39.8321	65.1233	0.3
5	4	15.6234	36.8452	0.2
6	5	4.4932	20.2341	0.1
7	6	1.0461	10.6239	0.1
8	7	0.2034	5.2318	0.1
9	8	0.0100	2.1348	0.0
10	9	0.000	0.5219	0.0

Evation: add(add(x,1), mul(x,x))

Code:

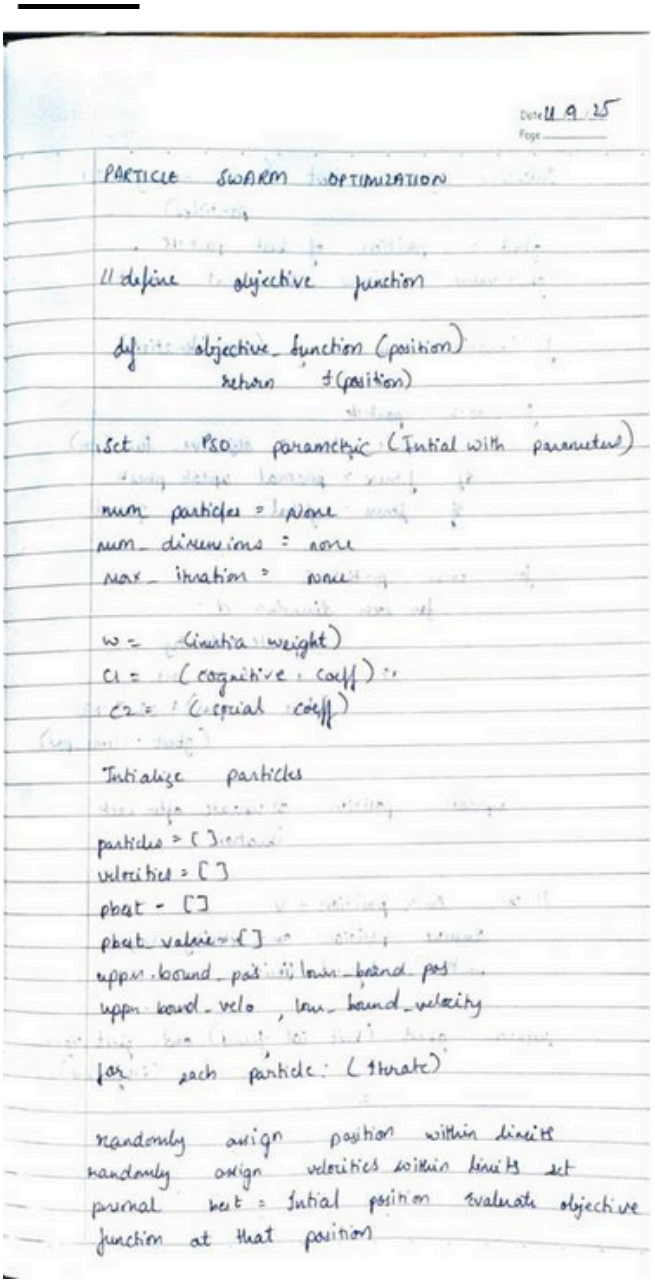
```
importnumpy as np
# Objective function (example: minimize sphere function)
def fitness(x):


    return np.sum(x**2)

# GA parameters
pop_size = 20
chrom_length = 5
generations = 50
mutation_rate = 0.1
# Initialization: random population in [-10, 10]
population = np.random.uniform(-10, 10, (pop_size, chrom_length))
for gen in range(generations):


    fitness_values = np.array([fitness(ind) for ind in population])
    # Selection (roulette wheel)
    fitness_inv = 1 / (fitness_values + 1e-6)
    probs = fitness_inv / np.sum(fitness_inv)
    parents_idx = np.random.choice(pop_size, size=pop_size, p=probs)
    parents = population[parents_idx]
    # Crossover (single point)
    offspring = []
    for i in range(0, pop_size, 2):

        p1, p2 = parents[i], parents[(i+1) % pop_size]
        point = np.random.randint(1, chrom_length)
        child1 = np.concatenate((p1[:point], p2[point:]))
        child2 = np.concatenate((p2[:point], p1[point:]))
        offspring.extend([child1, child2])
    offspring = np.array(offspring[:pop_size])
    # Mutation
    mutations = np.random.rand(pop_size, chrom_length) < mutation_rate
    mutation_values = np.random.uniform(-1, 1, (pop_size, chrom_length))
    offspring = offspring + mutations * mutation_values
    population = offspring



# Best solution
best_idx = np.argmin([fitness(ind) for ind in population])
print("Best solution:", population[best_idx])
print("Best fitness:", fitness(population[best_idx]))
```

OUTPUT: -

```
1BM23CS235-POTNURU ASHRITA
Best solution: [ 0.0301218   0.09859474 -0.13087039  0.01176386 -0.08049134]
Best fitness: 0.0343725495821183
```

Program 3: Particle Swarm Optimization for function optimization

Algorithm:



PARTICLE SWARM OPTIMIZATION

// define objective function

def objective_function (position)
return f(position)

Set PSO parameters (Initial with parameters)
num_particles = none
num_dimensions = none
max_iteration = none

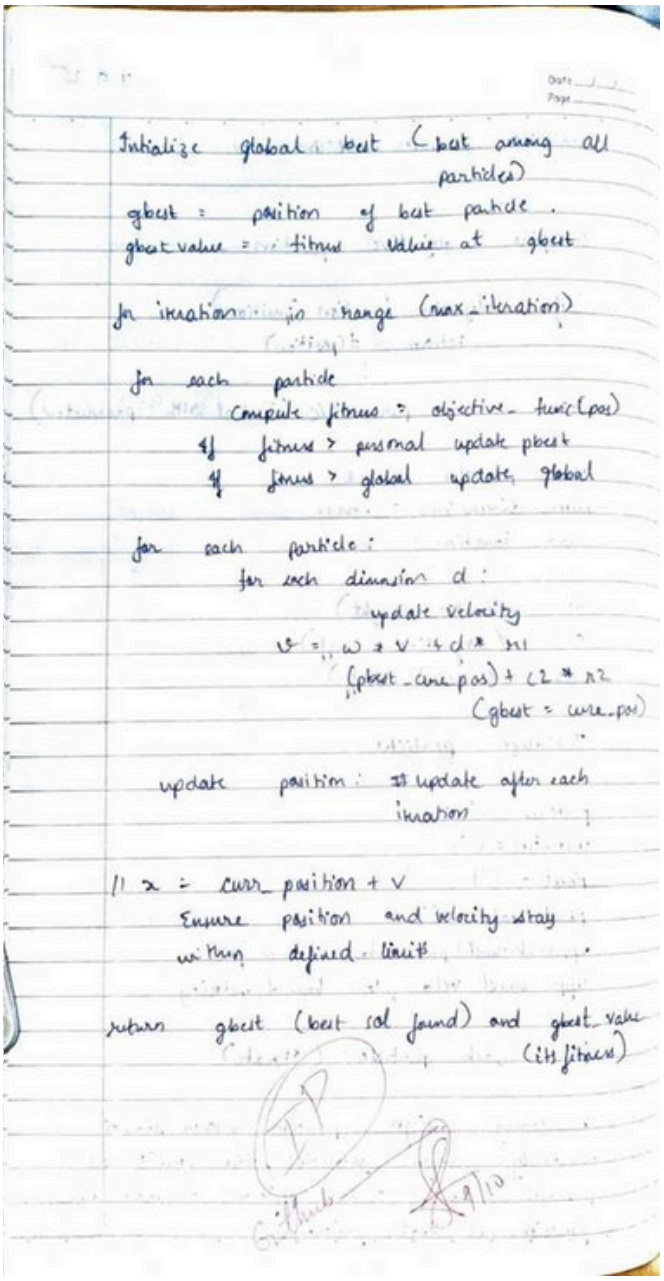
w = (inertia weight)
c1 = (cognitive coeff)
c2 = (social coeff)

Initialize particles

particles = [ ]
velocities = [ ]
pbest = [ ]
pbest_value = [ ]
upper_bound_pos , lower_bound_pos
upper_bound_velo , lower_bound_velocity

for each particle: (iterate)

randomly assign position within limits
randomly assign velocities within limits set
personal best = initial position evaluate objective function at that position



Initialize global best (best among all particles)

gbest = position of best particle.
gbest_value = fitness value at gbest

for iteration in range (max_iteration)

for each particle
Compute fitness = objective_func(pos)
if fitness > personal update pbest
if fitness > global update global

for each particle:
for each dimension d:
update velocity
v = w * v + d * r1
(pbest_cur_pos) + c2 * r2
(gbest - cur_pos)

update position: # update after each iteration

// x = curr_position + v
Ensure position and velocity stay within defined limits

return gbest (best sol found) and gbest_value (its fitness)

Code: -

```
import numpy as np
from PILimportImage
import matplotlib.pyplot as plt

# Loadimageasgrayscale(replace'your_image.jpg' with your image file)
img=Image.open('your_image.jpg').convert('L')
img_np = np.array(img)

#Fitnessfunction:Otsu'sbetween-classvariance for threshold t
def otsu_fitness(t, image):


    t = int(t[0])
    if t <= 0 or t >= 255:
        return 0
    hist,_=np.histogram(image,bins=256,range=(0,256))
    total_pixels = image.size

    weight_bg=np.sum(hist[:t])/total_pixels
    weight_fg=np.sum(hist[t:])/total_pixels
    if weight_bg == 0 or weight_fg == 0:

        return 0

    mean_bg=np.sum(np.arange(t)*hist[:t]) / np.sum(hist[:t])
    mean_fg=np.sum(np.arange(t,256)*hist[t:]) / np.sum(hist[t:])
    between_class_variance=weight_bg*weight_fg * (mean_bg - mean_fg) ** 2
    return between_class_variance

# PSO parameters
num_particles = 30
max_iter = 50
w = 0.7     #inertiaweight
c1 = 1.5    #cognitivecoefficient
c2 = 1.5    #socialcoefficient

# Initializeparticlesrandomly(thresholdvalues between 0 and 255)
particles=np.random.uniform(0,255,(num_particles, 1))
velocities = np.zeros_like(particles)

# Initializepersonalbests
pbest_pos = particles.copy()
pbest_scores=np.array([otsu_fitness(p,img_np) for p in particles])
# Initializeglobalbest
gbest_idx = np.argmax(pbest_scores)
gbest_pos = pbest_pos[gbest_idx].copy()
gbest_score = pbest_scores[gbest_idx]
for iteration in range(max_iter):
for i in range(num_particles):

        r1 = np.random.rand()
        r2 = np.random.rand()
        velocities[i] = (w * velocities[i] +
                         c1*r1*(pbest_pos[i]-particles[i]) +
                         c2*r2*(gbest_pos-particles[i]))
```

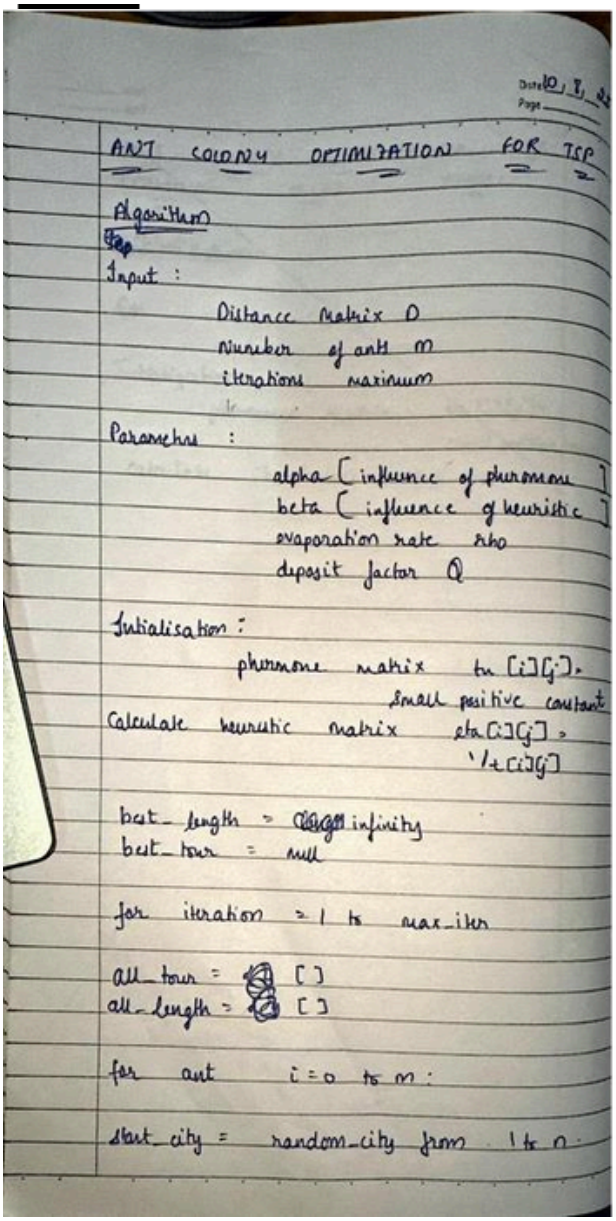
```
            particles[i] = particles[i] + velocities[i]
            particles[i] = np.clip(particles[i], 0, 255)

            fitness_val = otsu_fitness(particles[i], img_np)

            if fitness_val > pbest_scores[i]:

                pbest_scores[i] = fitness_val
                pbest_pos[i] = particles[i].copy()

        gbest_idx = np.argmax(pbest_scores)
        if pbest_scores[gbest_idx] > gbest_score:
            gbest_score = pbest_scores[gbest_idx]
            gbest_pos = pbest_pos[gbest_idx].copy()

        print(f"Iteration {iteration+1}/{max_iter}, Best Score: {gbest_score:.2f}, Best Threshold: {int(gbest_pos[0])}")

    # Apply best threshold to binarize image
    threshold = int(gbest_pos[0])
    binary_img = (img_np > threshold) * 255

    # Display original and thresholded images
    plt.subplot(1, 2, 1)
    plt.title("Original Image")
    plt.imshow(img_np, cmap='gray')
    plt.axis('off')

    plt.subplot(1, 2, 2)
    plt.title(f"Thresholded Image (T={threshold})")
    plt.imshow(binary_img, cmap='gray')
    plt.axis('off')
    plt.show()
```

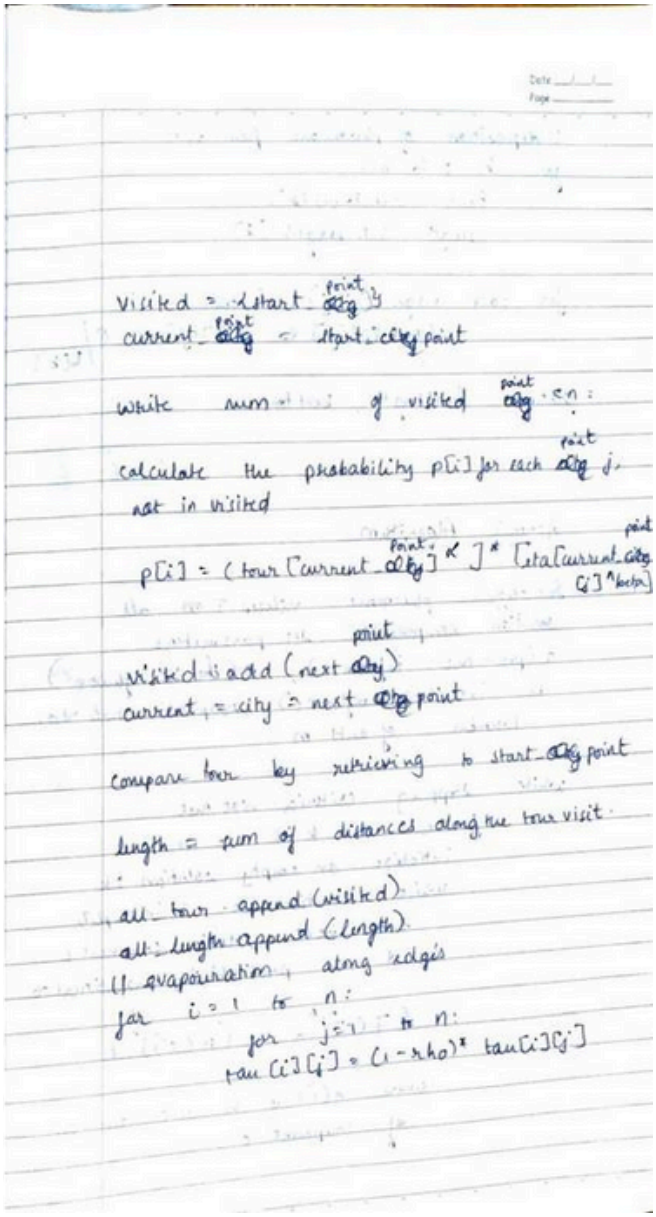
OUTPUT:

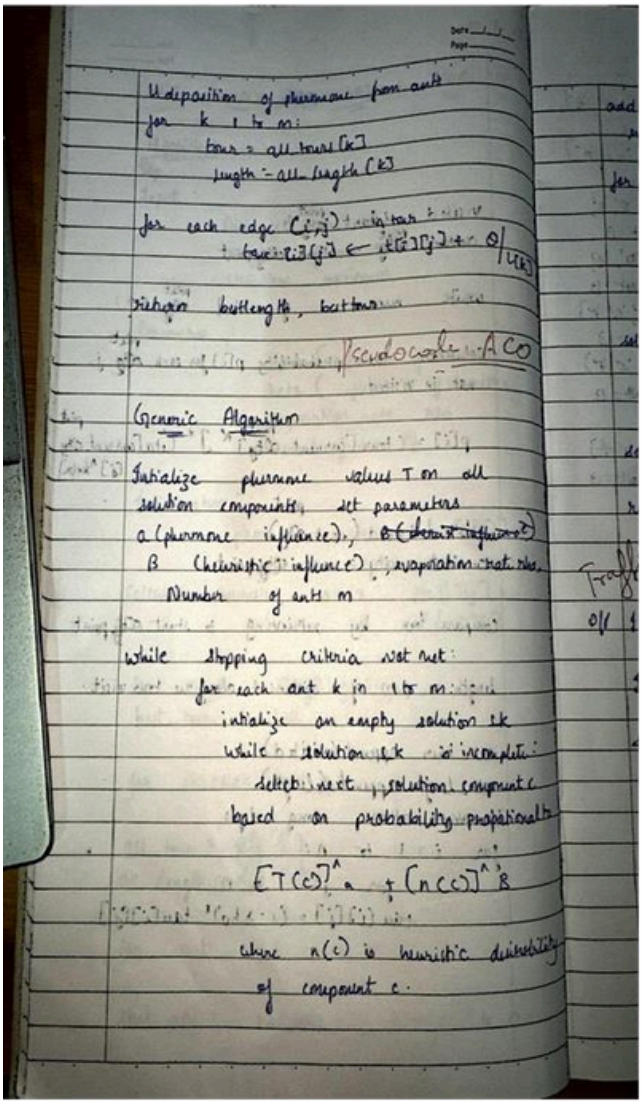
```
1bm23cs235-POTNURU ASHRITA
Gen 0 | best = 18.600 s | ['Pack', 'Pick', 'Place', 'Inspect', 'Label', 'Screw']
Gen 25 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 50 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 75 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 100 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 125 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 150 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 175 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 200 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 225 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Gen 250 | best = 18.400 s | ['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']

Best found sequence:
['Screw', 'Pick', 'Place', 'Inspect', 'Label', 'Pack']
Estimated total time: 18.400 s
```

Program 4: Ant colonization using travelling salesman problem

Algorithm:







Updation of pheromone from ants
for k = 1 to m:
tour = all_tours[k]
length = all_length[k]

for each edge (i,j) in tour:
tour[i][j] ← tour[i][j] + Q/length[k]

return best_length, best_tour

Pseudocode: ACO

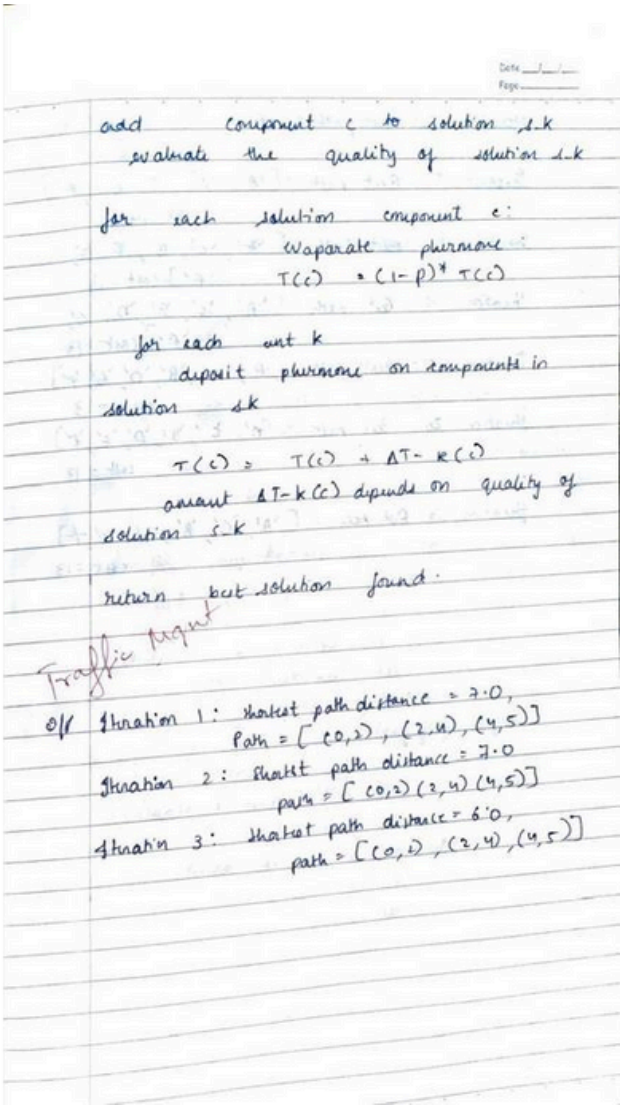
Genomic Algorithm

Initialize pheromone values T on all solution components, set parameters
α (pheromone influence), β (heuristic influence), evaporation rate, ρ
Number of ants m

while stopping criteria not met:
for each ant k in 1 to m:
initialize an empty solution sk
while solution sk is incomplete:
select next solution component c
based on probability proportional to

$$[T(c)]^{\alpha} * [n(c)]^{\beta}$$

where n(c) is heuristic desirability of component c.



add component c to solution s_k
evaluate the quality of solution s_k

for each solution component c:
Vaporate pheromone:
T(c) = (1-ρ) * T(c)

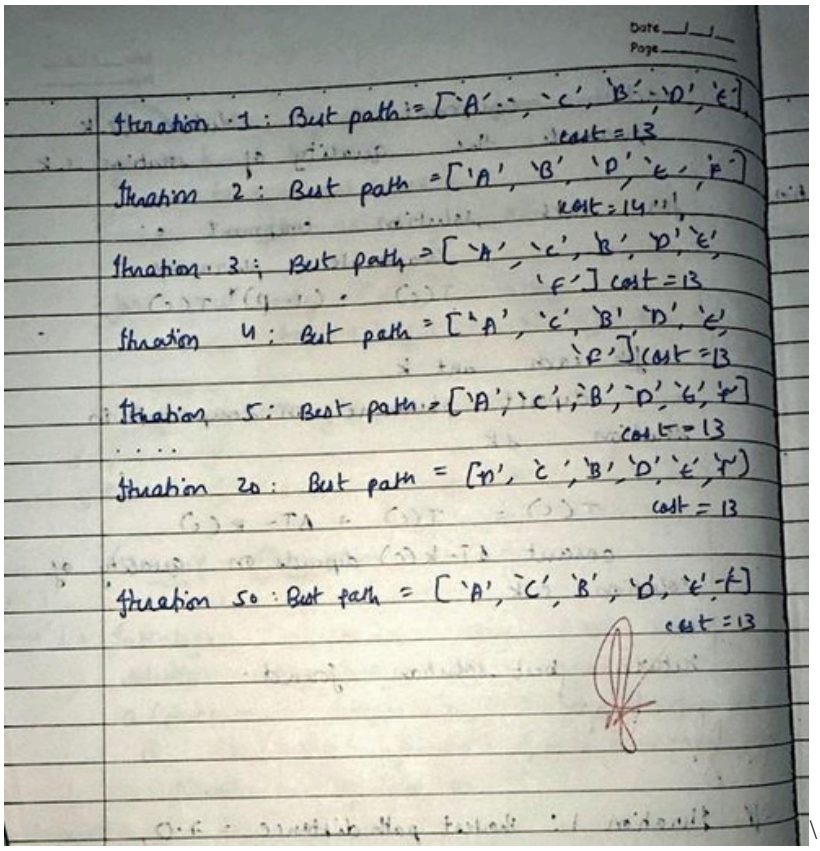
for each ant k
deposit pheromone on components in solution sk

T(c) = T(c) + ΔT-k(c)
amount ΔT-k(c) depends on quality of solution s_k

return best solution found.

Traffic light

Iteration 1: shortest path distance = 7.0,
Path = [(0,2), (2,4), (4,5)]
Iteration 2: Shortest path distance = 7.0
path = [(0,2) (2,4) (4,5)]
Iteration 3: Shortest path distance = 6.0,
path = [(0,2), (2,4), (4,5)]



CODE: -

```
import numpy as np

# Graph as adjacency matrix: 0 means no direct road
# Nodes: 0 - start, 4 - destination
graph = np.array([
[0, 2, 0, 1, 0],
[2, 0, 3, 2, 0],
[0, 3, 0, 0, 1],
[1, 2, 0, 0, 3],
[0, 0, 1, 3, 0]
])

num_nodes = graph.shape[0]
start_node = 0
end_node = 4

# Parameters
num_ants = 5
num_iterations = 10
alpha = 1.0 # pheromone influence
beta = 2.0 # heuristic influence (inverse of distance)
evaporation_rate = 0.5
pheromone_deposit = 1.0

# Initialize pheromone trails with a small positive number
pheromone = np.ones((num_nodes, num_nodes)) * 0.1

# Heuristic matrix (inverse of distance, avoid division by zero)
heuristic = np.zeros_like(graph, dtype=float)
foriinrange(num_nodes):

    forjin range(num_nodes):
```

```
        if graph[i, j] > 0:
            heuristic[i, j] = 1.0 / graph[i, j]

def choose_next_node(current, visited):
    probabilities = []
    neighbors = []
    for j in range(num_nodes):
        ifgraph[current,j]>0andjnotinvisited:
            tau=pheromone[current,j]**alpha
            eta = heuristic[current, j] ** beta
            probabilities.append(tau * eta)
            neighbors.append(j)
    probabilities = np.array(probabilities)
    if probabilities.sum() == 0:
        return None
    probabilities=probabilities/probabilities.sum()
    returnnp.random.choice(neighbors,p=probabilities)

def ant_walk():
    path = [start_node]
    visited = set(path)
    current = start_node
    while current != end_node:
        next_node=choose_next_node(current, visited)
        if next_node is None:
            # Dead end: restart path (or stop)
            return None
        path.append(next_node)
        visited.add(next_node)
        current = next_node
    return path

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

best_path = None
best_length = float('inf')
for iteration in range(num_iterations):
    all_paths = []
    for _ in range(num_ants):
        path = None
        while path is None:
            path = ant_walk()
        all_paths.append(path)

    # Evaporate pheromone
    pheromone *= (1 - evaporation_rate)
    #Depositpheromonebasedonpathquality
    for path in all_paths:
        length = path_length(path)
        if length < best_length:
        best_length = length
        best_path = path
        deposit_amount=pheromone_deposit / length
        for i in range(len(path)-1):
```

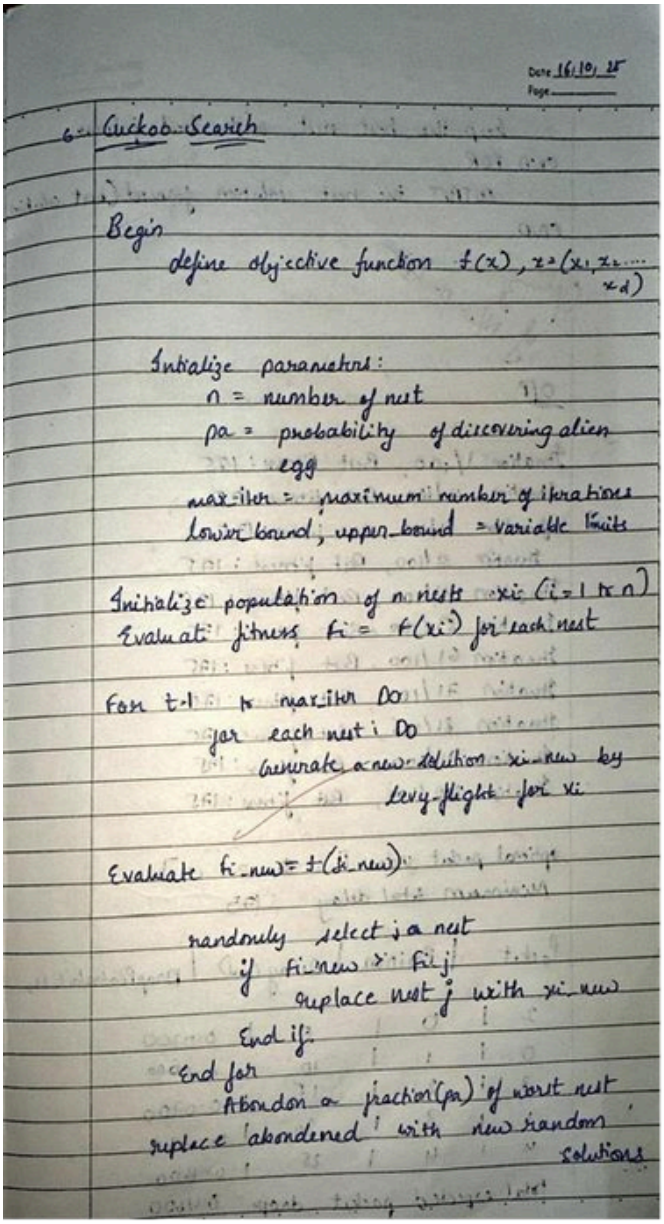
```
            pheromone[path[i], path[i+1]] += deposit_amount
            pheromone[path[i+1], path[i]] += deposit_amount # undirected graph

        print(f"Iteration {iteration+1}: Best path so far: {best_path} with length {best_length}")

    print("\nFinal best path found:", best_path)
    print("Path length:", best_length)
```

OUTPUT: -

```
1BM23CS235-POTNURU ASHRITA
Iteration 1: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 2: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 3: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 4: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 5: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 6: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 7: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 8: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 9: Best path so far: [0, np.int64(3), np.int64(4)] with length 4
Iteration 10: Best path so far: [0, np.int64(3), np.int64(4)] with length 4

Final best path found: [0, np.int64(3), np.int64(4)]
Path length: 4
```

Program 5: Cukoo Search using network packet transmission

Algorithm:



Date 16.10.25
Page

6. Cuckoo Search

Begin
define objective function f(x), x=(x1, x2, ... xd)

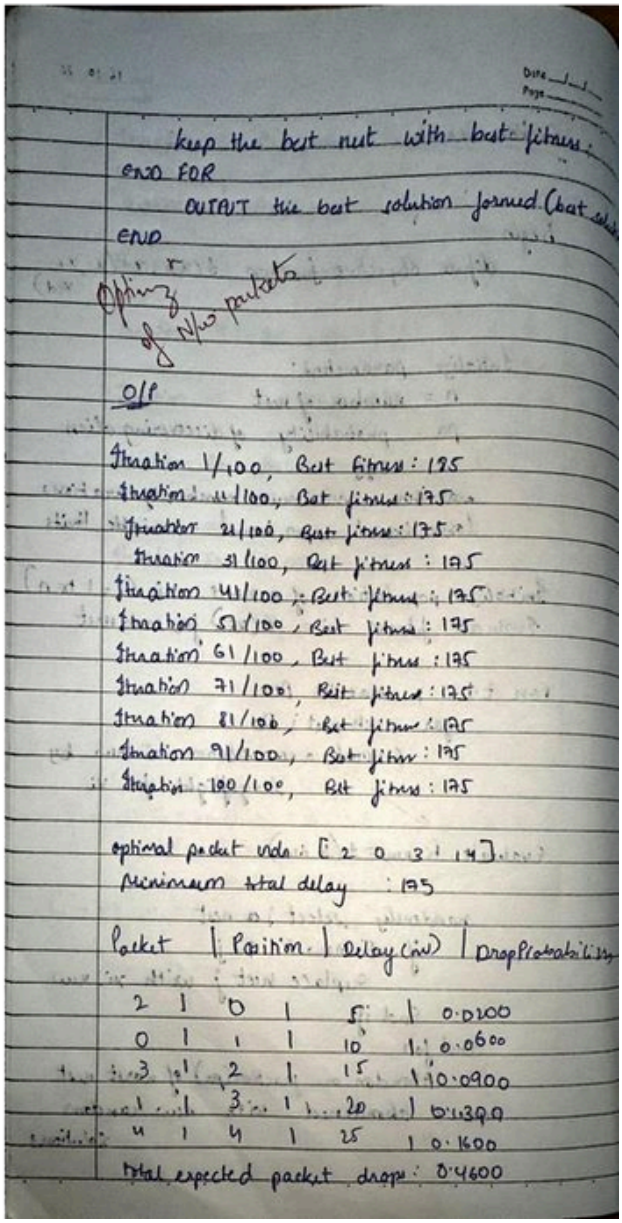
Initialize parameters:
n = number of nest
pa = probability of discovering alien egg
max_iter = maximum number of iterations
lower_bound, upper_bound = variable limits

Initialize population of n nests xi (i=1 to n)
Evaluate fitness fi = f(xi) for each nest

For t=1 to max_iter DO
for each nest i DO
Generate a new solution xi_new by Levy-flight for xi

Evaluate fi_new = f(xi_new)

randomly select j a nest
if fi_new > fij
replace nest j with xi_new
End if
End for
Abandon a fraction(pa) of worst nest
replace abandened with new random solutions



keep the best nest with best fitness
END FOR
OUTPUT the best solution formed (best

END

Optimize of N/w packets

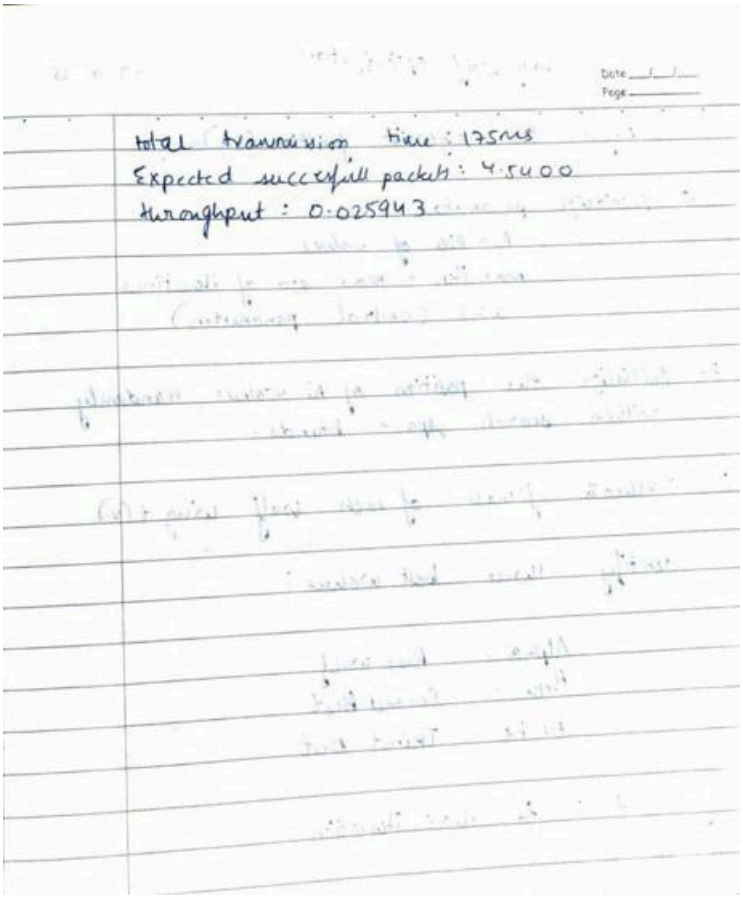
O/P

Iteration 1/100, Best fitness: 175
Iteration 11/100, Best fitness: 175
Iteration 21/100, Best fitness: 175
Iteration 31/100, Best fitness: 175
Iteration 41/100, Best fitness: 175
Iteration 51/100, Best fitness: 175
Iteration 61/100, Best fitness: 175
Iteration 71/100, Best fitness: 175
Iteration 81/100, Best fitness: 175
Iteration 91/100, Best fitness: 175
Iteration 100/100, Best fitness: 175

optimal packet order: [2 0 3 1 4]
Minimum total delay: 175

Packet	Position	Delay (ms)	DropProbability
2	1	5	0.0200
0	1	10	0.0600
3	2	15	0.0900
1	3	20	0.1300
4	4	25	0.1600

Total expected packet drops: 0.4600



CODE: -

```
importnumpy as np

#Example packet delays (in ms)
packet_delays = [10, 20, 5, 15, 25]
#Objective function: minimize total completion time for given packet order
defobjective(order):

    total_time = 0
    current_time = 0
    foriin order:
        current_time += packet_delays[i]
        total_time += current_time
    return total_time

#Generate a random solution (permutation of packets)
defrandom_solution(n):
    solution = np.arange(n)
    np.random.shuffle(solution)
    return solution

#Levyflight step (for continuous problems, adapted for permutation with swap)
deflevy_flight(solution):
    n=len(solution)
    #Swap two random positions
    i,j=np.random.choice(n, 2, replace=False)
    new_solution = solution.copy()
    new_solution[i], new_solution[j] = new_solution[j], new_solution[i]
    return new_solution
```

```python
def cuckoo_search(n_packets, n_nests=15, n_iterations=100, pa=0.25):
    # Initialize nests with random solutions
    nests = [random_solution(n_packets) for _ in range(n_nests)]
    fitness = np.array([objective(nest) for nest in nests])

    best_idx = np.argmin(fitness)
    best_nest = nests[best_idx].copy()
    best_fitness = fitness[best_idx]

    for iter in range(n_iterations):

        # Generate new solutions by Levy flights
        for i in range(n_nests):
            new_nest = levy_flight(nests[i])
            new_fitness = objective(new_nest)

            # Greedy selection: keep better solutions
            if new_fitness < fitness[i]:
                nests[i] = new_nest
                fitness[i] = new_fitness
                # Update global best
                if new_fitness < best_fitness:
                    best_fitness = new_fitness
                    best_nest = new_nest.copy()

        # Abandon some nests and generate new ones
        for i in range(n_nests):
            if np.random.rand() < pa:
                nests[i] = random_solution(n_packets)
                fitness[i] = objective(nests[i])

                # Update global best
                if fitness[i] < best_fitness:
                    best_fitness = fitness[i]
                    best_nest = nests[i].copy()

        if iter % 10 == 0 or iter == n_iterations - 1:
            print(f"Iteration {iter+1}/{n_iterations}, Best fitness: {best_fitness}")

    return best_nest, best_fitness

# Run the Cuckoo Search optimization
best_order, best_cost = cuckoo_search(len(packet_delays))
print("\nOptimal packet order (indices):", best_order)
print("Minimum total delay:", best_cost)
```

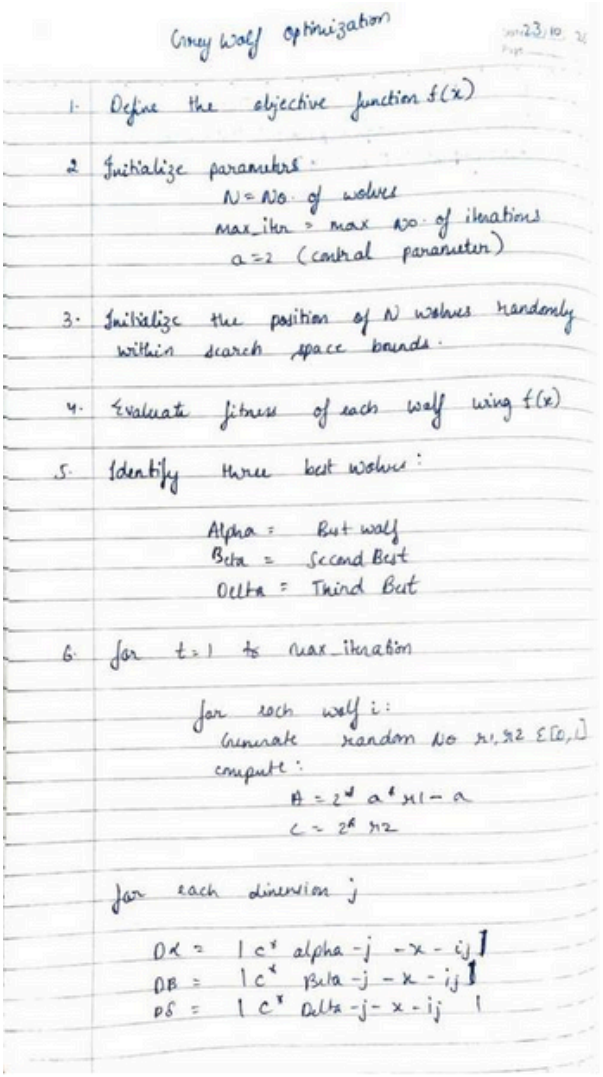
OUTPUT: -

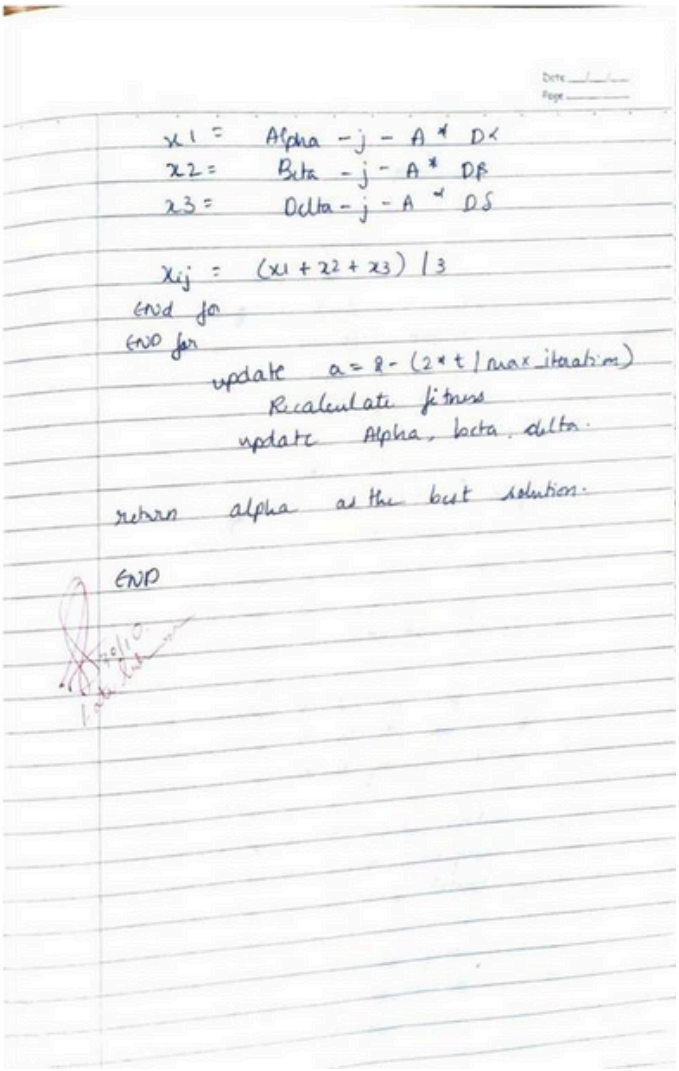
```
1BM23CS235-POTNURU ASHRITA
Iteration 1/100, Best fitness: 185
Iteration 11/100, Best fitness: 175
Iteration 21/100, Best fitness: 175
Iteration 31/100, Best fitness: 175
Iteration 41/100, Best fitness: 175
Iteration 51/100, Best fitness: 175
Iteration 61/100, Best fitness: 175
Iteration 71/100, Best fitness: 175
Iteration 81/100, Best fitness: 175
Iteration 91/100, Best fitness: 175
Iteration 100/100, Best fitness: 175

Optimal packet order (indices): [2 0 3 1 4]
Minimum total delay: 175
```

[ ]:

Program 6: Grey Wolf Optimization

Algorithm:





CODE: -

```
# gwo_reliability.py

# Grey Wolf Optimization (GWO) for Reliability-Redundancy Allocation (series system)

# Python 3.9+

from future import annotations

import math

import random

from dataclasses import dataclass
```

```
        from typing import List, Optional, Tuple

        class RRAData:

        p: List[float] # component reliability for subsystem i (0)

    c: List[float] # cost per component in subsystem i

        w: Optional[List[float]] = None # weight per component (optional)

        max_red: Optional[List[int]] = None # max redundancy per subsystem (>=1)

        budget: Optional[float] = None

        weight_limit: Optional[float] = None

        def post_init (self):

        m = len(self.p)

        assert len(self.c) == m

        if self.w is not None:

        assert len(self.w) == m

        if self.max_red is None:

        self.max_red = [5] * m # default caps

        else:

        assert len(self.max_red) == m

        def subsystem_reliability(p: float, x: int) -> float:

        # Reliability of x identical parallel components

        x = max(1, x)

        return 1.0 - (1.0 - p) ** x

        def system_reliability(x: List[int], data: RRAData) -> float:

        R = 1.0

        for xi, pi in zip(x, data.p):

        Ri = subsystem_reliability(pi, xi)

        R *= Ri

        if R <= 0.0:

        return 0.0

        return R

        def totals(x: List[int], data: RRAData) -> Tuple[float, float]:
```

```
return tot_cost, tot_weight

def penalty(x: List[int], data: RRAData) -> float:

tot_cost, tot_weight = totals(x, data)

v_cost = max(0.0, (tot_cost - (data.budget if data.budget is not None else float('inf'))))

v_weight = 0.0

if data.weight_limit is not None and data.w is not None:

v_weight = max(0.0, tot_weight - data.weight_limit)

# Scale penalties relative to typical magnitudes

# Add small eps to avoid division by zero if limits are None

scale_c = (data.budget if data.budget is not None else (tot_cost + 1.0))

scale_w = (data.weight_limit if data.weight_limit is not None else (tot_weight + 1.0))

return 1e3 * (v_cost / (scale_c + 1e-9))**2 + 1e3 * (v_weight / (scale_w + 1e-9))**2

def objective(x_cont: List[float], data: RRAData) -> float:

x = []

for val, xmax in zip(x_cont, data.max_red):

xi = int(round(val))

xi = max(1, min(xi, xmax))

x.append(xi)

R = system_reliability(x, data)

pen = penalty(x, data)

return -(R) + pen # minimize

def clamp_position(pos: List[float], data: RRAData) -> List[float]:

out = []

for v, xmax in zip(pos, data.max_red):

out.append(min(max(v, 1.0), float(xmax)))

return out

class GreyWolfOptimizer:

def init (self,

data: RRAData,
```

```
n_wolves: int = 30,

n_iters: int = 300,

a0: float = 2.0,

seed: Optional[int] = 42):

self.data = data

self.m = len(data.p)

self.n_wolves = n_wolves

self.n_iters = n_iters

self.a0 = a0

if seed is not None:

random.seed(seed)

self.pop: List[List[float]] = [

[random.uniform(1.0, float(xmax)) for xmax in data.max_red] for _ in range(n_wolves)

]

self.fvals: List[float] = [objective(x, data) for x in self.pop]

self.alpha = None # type: Optional[List[float]]

self.beta = None

self.delta = None

self.alpha_val = float('inf')

self.beta_val = float('inf')

self.delta_val = float('inf')

self._update_leaders()

def _update_leaders(self):

ranked = sorted(zip(self.fvals, self.pop), key=lambda t: t[0])

self.alpha_val, self.alpha = ranked[0]

self.beta_val, self.beta = ranked[1]

self.delta_val, self.delta = ranked[2]

def step(self, t: int):

a = self.a0 * (1 - t / max(1, self.n_iters - 1))
```

```
new_pop: List[List[float]] = []

new_f: List[float] = []

for i in range(self.n_wolves):

X = self.pop[i]

X1 = []

X2 = []

X3 = []

for d in range(self.m):

r1a, r2a = random.random(), random.random()

r1b, r2b = random.random(), random.random()

r1c, r2c = random.random(), random.random()

A1 = 2 * a * r1a - a

C1 = 2 * r2a

A2 = 2 * a * r1b - a

C2 = 2 * r2b

A3 = 2 * a * r1c - a

C3 = 2 * r2c

D_alpha = abs(C1 * self.alpha[d] - X[d])

D_beta = abs(C2 * self.beta[d] - X[d])

D_delta = abs(C3 * self.delta[d] - X[d])

X1d = self.alpha[d] - A1 * D_alpha

X2d = self.beta[d] - A2 * D_beta

X3d = self.delta[d] - A3 * D_delta

X1.append(X1d); X2.append(X2d); X3.append(X3d)

X_new = [(x1 + x2 + x3) / 3.0 for x1, x2, x3 in zip(X1, X2, X3)]

X_new = clamp_position(X_new, self.data)

f_new = objective(X_new, self.data)

new_pop.append(X_new)

new_f.append(f_new)
```

```
self.pop = new_pop

self.fvals = new_f

self._update_leaders()

def run(self, verbose: bool = True) -> Tuple[List[int], float, dict]:

history = []

for t in range(self.n_iters):

self.step(t)

if verbose and (t % max(1, self.n_iters // 10) == 0 or t == self.n_iters - 1):

print(f"[iter {t+1:4d}] best (−R+pen)={self.alpha_val:.6f}")

history.append(self.alpha_val)

best_cont = self.alpha

best_x = [int(round(v)) for v in best_cont]

# clamp to bounds

best_x = [max(1, min(xi, xmax)) for xi, xmax in zip(best_x, self.data.max_red)]

best_R = system_reliability(best_x, self.data)

feas_pen = penalty(best_x, self.data)

return best_x, best_R, {

"objective": -best_R + feas_pen,

"cost_weight": totals(best_x, self.data),

"history": history

}

if name == " main ":

data = RRAData(

p=[0.90, 0.92, 0.88, 0.93, 0.91],

c=[12.0, 10.0, 9.0, 11.0, 8.0],

w=[1.6, 1.2, 1.4, 1.5, 1.0], # optional weight per component

max_red=[6, 6, 6, 6, 6], # cap per subsystem

budget=120.0, # total cost constraint (optional)

weight_limit=18.0 # total weight constraint (optional)
```

```
)
gwo = GreyWolfOptimizer(
data=data,
n_wolves=35,
n_iters=400,
a0=2.0,
seed=123
)
best_x, best_R, info = gwo.run(verbose=True)
tot_cost, tot_weight = info["cost_weight"]
print("\n=== GWO Result (Reliability Optimization) ===")
print("Best redundancy vector x (per subsystem):", best_x)
print("System reliability R(x):", f"{best_R:.8f}")
print("Total cost:", f"{tot_cost:.2f}")
print("Total weight:", f"{tot_weight:.2f}")
print("Feasible (budget/weight):",
("Yes" if (data.budget is None or tot_cost <= data.budget) and
(data.weight_limit is None or tot_weight <= data.weight_limit) else "No"))
```

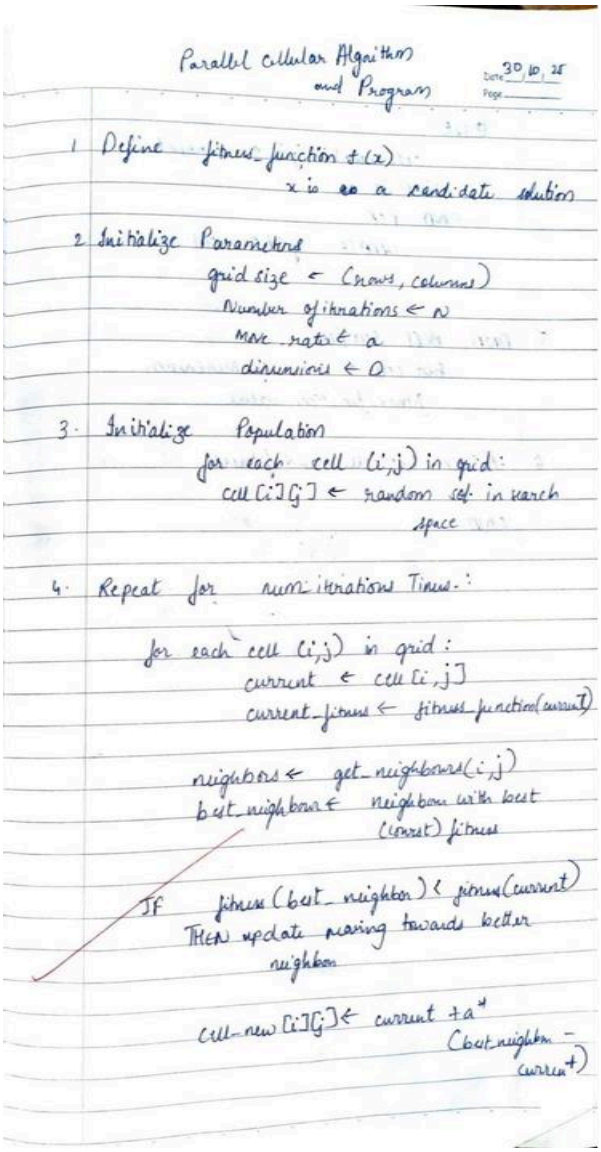
OUTPUT:-

Output Clear

```
[iter    1] best (-R+pen)=-0.963059
[iter   41] best (-R+pen)=-0.920857
[iter   81] best (-R+pen)=-0.974981
[iter  121] best (-R+pen)=-0.974981
[iter  161] best (-R+pen)=-0.976440
[iter  201] best (-R+pen)=-0.976440
[iter  241] best (-R+pen)=-0.976440
[iter  281] best (-R+pen)=-0.976440
[iter  321] best (-R+pen)=-0.976440
[iter  361] best (-R+pen)=-0.976440
[iter  400] best (-R+pen)=-0.976440

=== GWO Result (Reliability Optimization) ===
Best redundancy vector x (per subsystem): [2, 2, 3, 2, 3]
System reliability R(x): 0.97644026
Total cost: 117.00
Total weight: 15.80
Feasible (budget/weight): Yes
```

Program 7: Parallel Cellular Algorithms And Program by suing noise reduction image porcessing

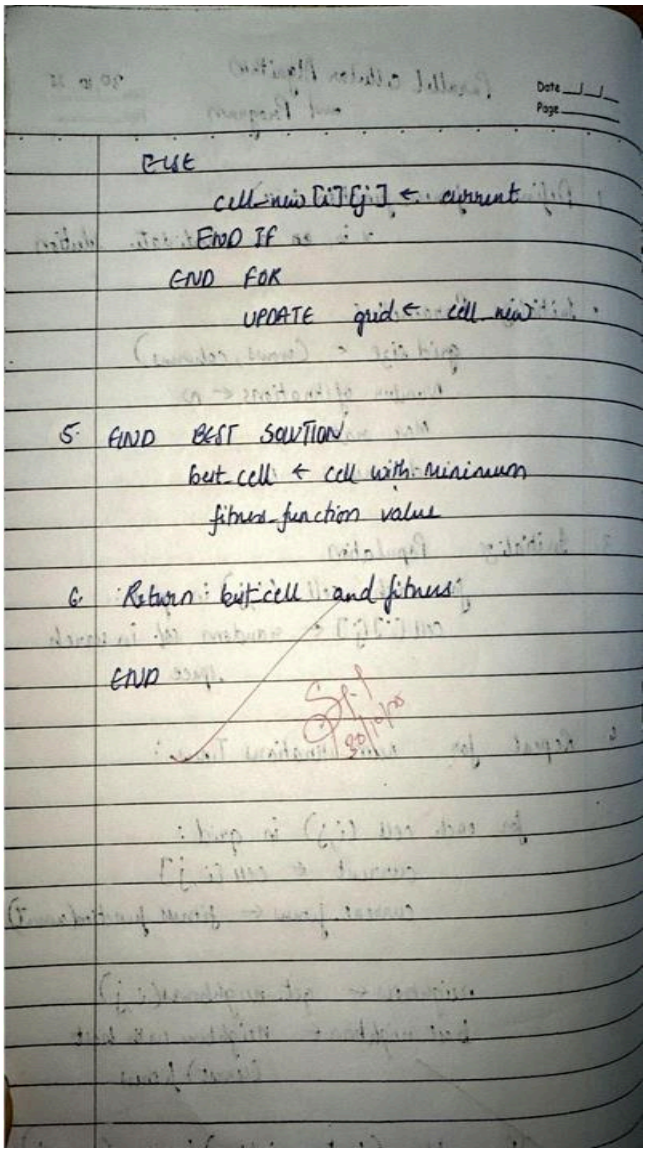
Algorithm:-



Parallel cellular Algorithm and Program

Date 30/10/25

1. Define fitness_function f(x)
   x is a candidate solution
2. Initialize Parameters
   grid size ← (rows, columns)
   Number of iterations ← n
   Move rate ← a
   dimensions ← D
3. Initialize Population
   for each cell (i,j) in grid:
   cell[i][j] ← random set in search space
4. Repeat for num_iterations Times:
   for each cell (i,j) in grid:
   current ← cell[i,j]
   current_fitness ← fitness_function(current)
   neighbors ← get_neighbors(i,j)
   best_neighbor ← neighbor with best (lowest) fitness
   IF fitness(best_neighbor) < fitness(current)
   THEN update moving towards better neighbor
   cell_new[i][j] ← current + a* (best_neighbor - current)



ELSE
cell_new[i][j] ← current
END IF
END FOR
UPDATE grid ← cell_new
5. FIND BEST SOLUTION
best_cell ← cell with minimum fitness_function value
6. Return best_cell and fitness
END

Image Processing

Initial Image:

20	30	40	30	20
30	100	150	100	30
40	150	255	150	40
30	100	150	100	30
20	30	40	30	20

Iteration 1:

30	42	54	42	30
42	96	134	96	42
54	134	208	134	54
42	96	134	96	42
30	42	54	42	30

Iteration 2:

39	51	63	51	39
51	92	122	92	51
63	122	174	122	63
51	92	122	92	51
39	51	63	51	39

.....

Iteration 5:

57	67	75	67	57
67	85	98	85	67
75	98	119	98	75
67	85	98	85	67
57	67	75	67	57

Key Improvements in Research Paper:

→ Neighbourhood:

Early CAs often used very simple neighbourhoods (eg 4 to 9 neighbour)

Now CAs works on larger and adaptive neighbour (25 neighbour models)

→ Scalability to larger grids.

→ Recent works/techniques made the number of iterations to be reduced

So shorter runtime

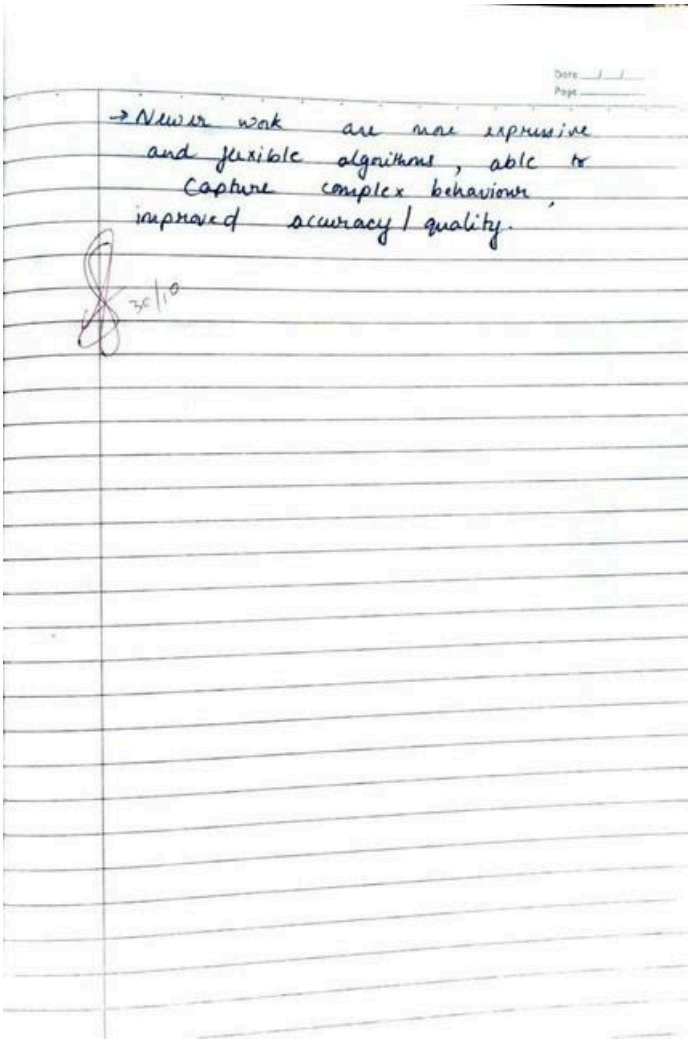
→ Better parallel implementation techniques

Old algorithms suffered from synchronization overheads, insufficient memory access, or poor use of data locality.

Benefit: More efficient per cell update, better scaling, less overhead.

→ Old CA's focused on shared-memory or single-machine parallelism.

→ Recent CA's work is distributed/cloud/ Internet-scale frameworks



CODE: -

```
# ---SIMPLEPARALLEL CELLULAR ALGORITHM (NO IMPORTS) ---
# Example grayscale "image" (each pixel: 0–255)
image = [


    [ 20, 30, 40, 30, 20], [ 30,
    100, 150, 100, 30], [ 40,
    150, 255, 150, 40], [ 30,
    100, 150, 100, 30], [ 20,
    30, 40, 30, 20]
]
# Parameters
iterations = 5
alpha = 0.4         # number of iterations
                    # blending factor (how much neighbor average influences pixel)
height = len(image)
width = len(image[0])
defget_neighbors(img, x, y):

    """Return 3x3 neighborhood around (x,y) with edge handling."""
    neighbors = []
    for i in range(x-1, x+2):
```

```
        for j in range(y-1, y+2):
            if 0 <= i < height and 0 <= j < width:
                neighbors.append(img[i][j])
    return neighbors

def parallel_update(img):
    """Perform one parallel update step."""
    new_img = [[0]*width for _ in range(height)]
    for i in range(height):
        for j in range(width):
            neighbors = get_neighbors(img, i, j)
            mean_value = sum(neighbors) / len(neighbors)
            new_img[i][j] = int((1 - alpha) * img[i][j] + alpha * mean_value)
    return new_img

def show_image(img):
    """Print the image matrix (simulated grayscale view)."""
    for row in img:
        print(" ".join(f"{v:3}" for v in row))
    print("-" * (width * 4))

# --- Run iterations and show results ---
print("Initial Image:")
show_image(image)

fortin range(1, iterations + 1):
    image = parallel_update(image)
    print(f"Iteration {t}:")
    show_image(image)
```

OUTPUT: -

```
P.Ashrita 1BM23CS235
Initial Image:
 20  30  40  30  20
 30 100 150 100  30
 40 150 255 150  40
 30 100 150 100  30
 20  30  40  30  20
--------------------
Iteration 1:
 30  42  54  42  30
 42  96 134  96  42
 54 134 208 134  54
 42  96 134  96  42
 30  42  54  42  30
--------------------
Iteration 2:
 39  51  63  51  39
 51  92 122  92  51
 63 122 174 122  63
 51  92 122  92  51
 39  51  63  51  39
--------------------
Iteration 3:
 46  58  69  58  46
 58  89 112  89  58
 69 112 150 112  69
 58  89 112  89  58
 46  58  69  58  46
--------------------
Iteration 4:
 52  63  73  63  52
 63  87 104  87  63
 73 104 132 104  73
 63  87 104  87  63
 52  63  73  63  52
--------------------
Iteration 5:
 57  67  75  67  57
 67  85  98  85  67
 75  98 119  98  75
 67  85  98  85  67
 57  67  75  67  57
--------------------
```