VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB RECORD

Bio Inspired Systems (23CS5BSBIS)

Submitted by

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in partial fulfilment for the award of the degree of

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in
COMPUTER SCIENCE AND ENGINEERING

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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 **Parth Jain (1BM23CS357),** who is a Bonafide student of **B.M.S. College of Engineering.** It is in partial fulfilment 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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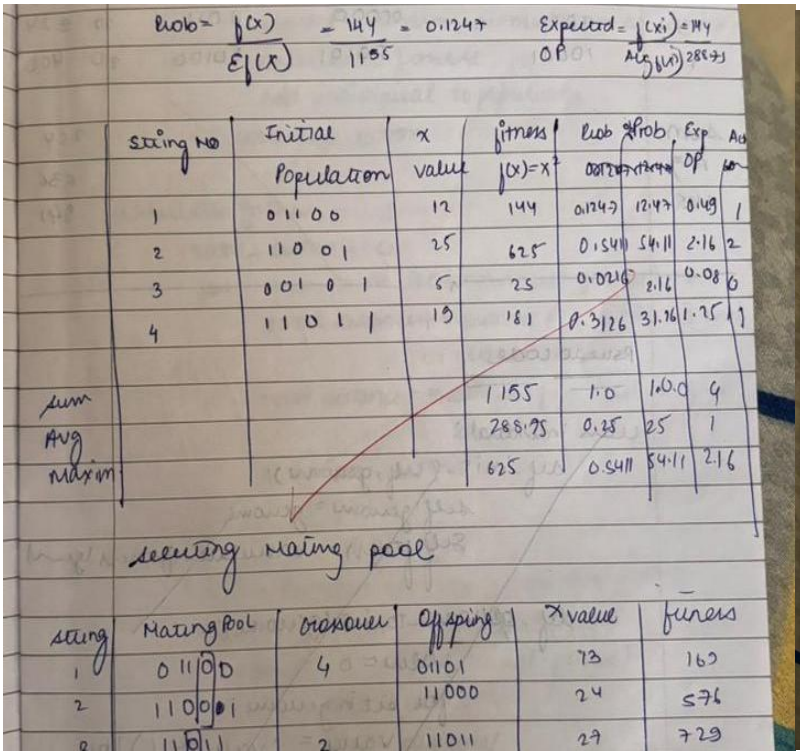
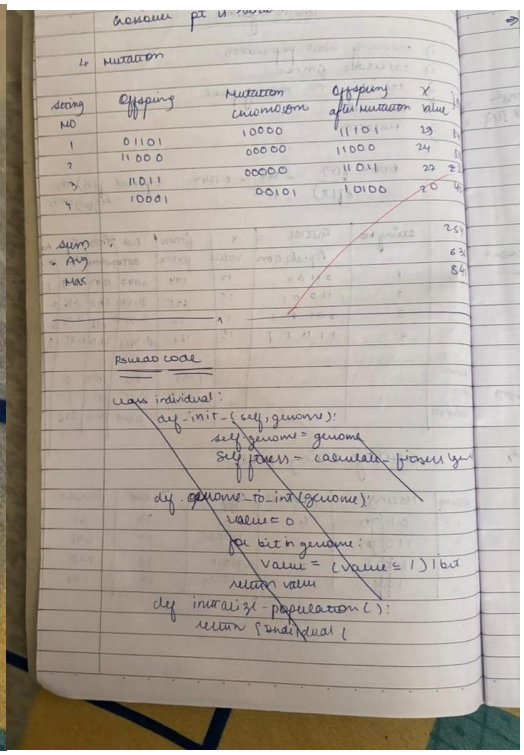
Github Link:
https://github.com/parthjain21108/BIS_LAB

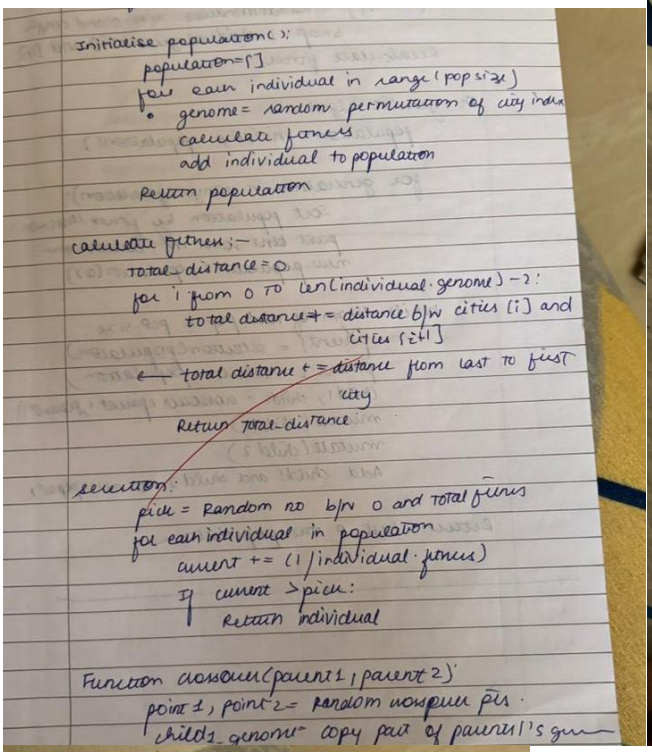
Program 1

To find the shortest route visiting all the cities exactly once and returning to start, using Genetic algorithm

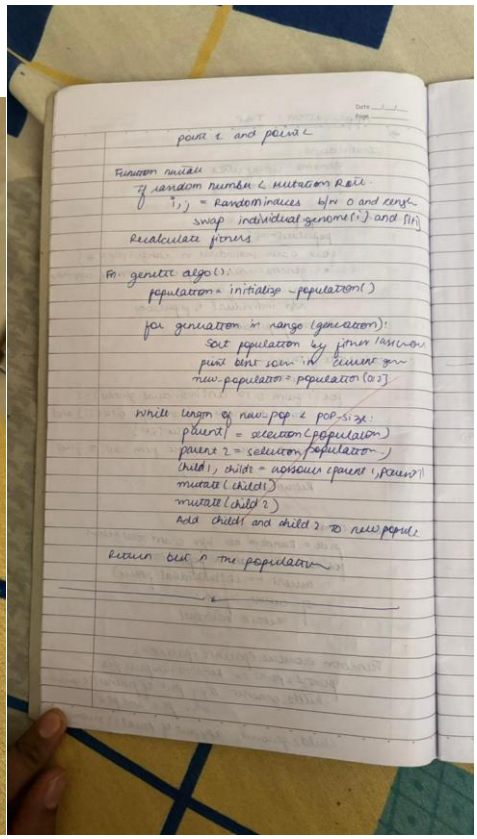
Algorithm:



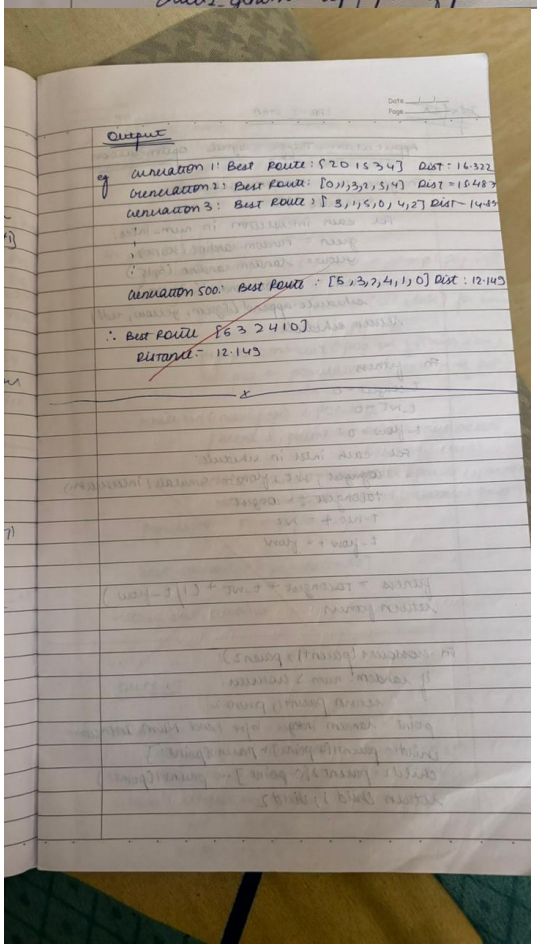




```
Initialise population():
    population=[]
    for each individual in range(pop size)
        genome = random permutation of city indices
        calculate fitness
        add individual to population
    Return population

calculate fitness:-
    total_distance = 0
    for i from 0 to len(individual.genome) - 2:
        total distance += distance b/w cities[i] and cities[i+1]
    ← total distance += distance from last to first city
    Return total_distance

selection:
    pick = Random no b/w 0 and total fitness
    for each individual in population
        current += (1/individual.fitness)
        If current > pick:
            Return individual

Function crossover(parent1, parent2)
    point 1, point 2 = random crossover pts.
    child1_genome = copy part of parent1's ge
```



```
point 1 and point 2

Function mutate
    If random number < mutation Rate:
        i, j = Random indices b/w 0 and length
        swap individual.genome[i] and [j]
    Recalculate fitness

Fn. genetic algo():
    population = initialize_population()

    for generation in range(generations):
        Sort population by fitness
        print best score in current gen
        new_population = population[0:2]

        While length of new_pop < POP_SIZE:
            parent1 = selection(population)
            parent2 = selection(population)
            child1, child2 = crossover(parent1, parent2)
            mutate(child1)
            mutate(child2)
            Add child1 and child2 to new popul

    Return best n the population
```



```
Output

eg  Generation 1: Best Route: [2 0 1 5 3 4]  Dist: 16.322
    Generation 2: Best Route: [0, 1, 3, 2, 5, 4]  Dist = 15.48
    Generation 3: Best Route: [3, 1, 5, 0, 4, 2]  Dist = 14.49
    .
    .
    .
    Generation 500: Best Route = [5, 3, 2, 4, 1, 0]  Dist: 12.143

∴ Best Route [5 3 2 4 1 0]
  Distance = 12.143
```

Code:

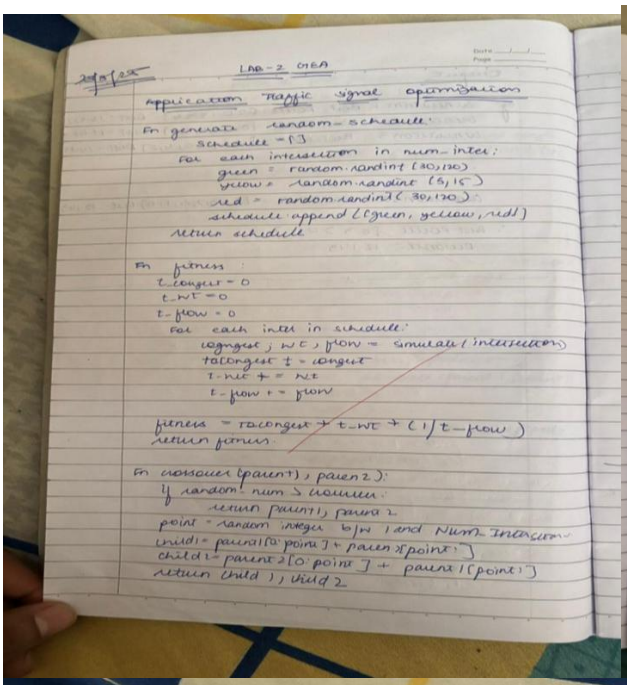
```
import random
import math

# Parameters
POP_SIZE = 20
MUTATION_RATE = 0.1
GENERATIONS = 4
X_MIN, X_MAX = 0, 10

# Fitness function
def fitness(x):
    return math.sin(x) * x

# Create initial population (list of real numbers)
def initial_population():
    return [random.uniform(X_MIN, X_MAX) for _ in range(POP_SIZE)]

# Tournament selection
def select(population):
    contenders = random.sample(population, 3)
    return max(contenders, key=fitness)

# Crossover (average)
def crossover(p1, p2):
    return (p1 + p2) / 2

# Mutation (small random change)
def mutate(x):
    if random.random() < MUTATION_RATE:
        x += random.uniform(-0.5, 0.5)
        x = max(min(x, X_MAX), X_MIN)
    return x

# Genetic Algorithm
def genetic_algorithm():
    population = initial_population()

    for generation in range(GENERATIONS):
        new_population = []

        for _ in range(POP_SIZE):
            parent1 = select(population)
            parent2 = select(population)
            child = crossover(parent1, parent2)
            child = mutate(child)
            new_population.append(child)
```

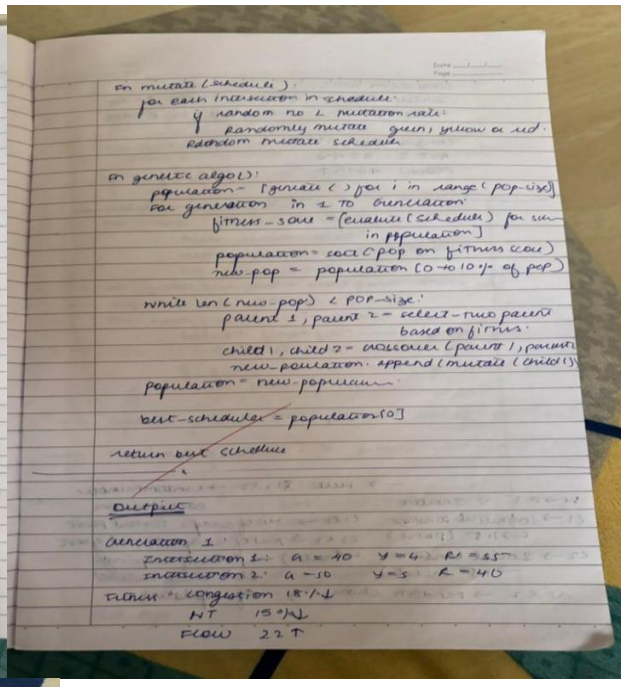
```
        population = new_population
        best = max(population, key=fitness)
        print(f"Gen {generation}: Best x = {best:.4f}, f(x) = {fitness(best):.4f}")

    return best

# Run
best_solution = genetic_algorithm()
print("\nBest solution found:")
print(f"x = {best_solution:.4f}")
print(f"f(x) = {fitness(best_solution):.4f}")
```

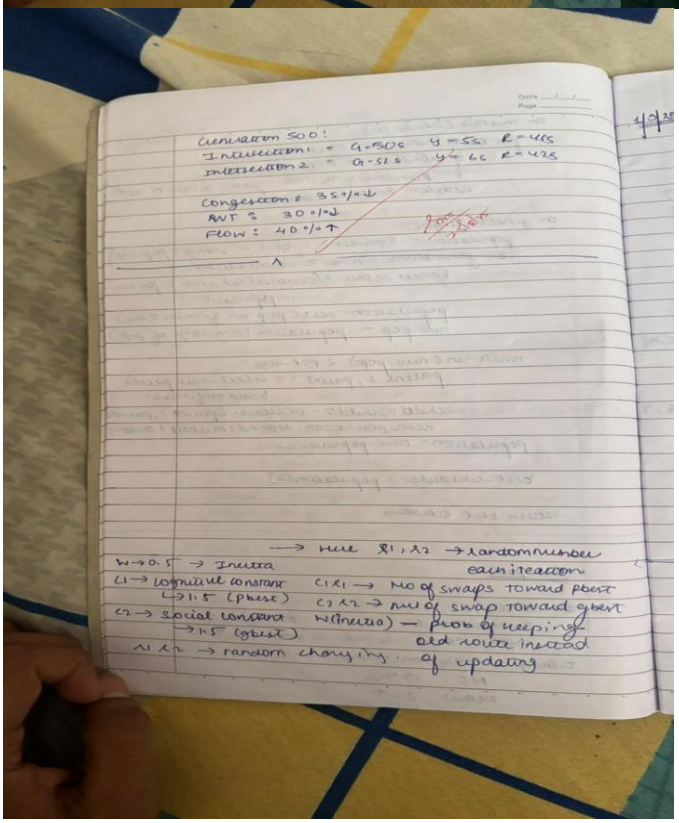
Program 2

To find the shortest route visiting all the cities exactly once and returning to start, using Gene Expression algorithm

Algorithm:







Code:

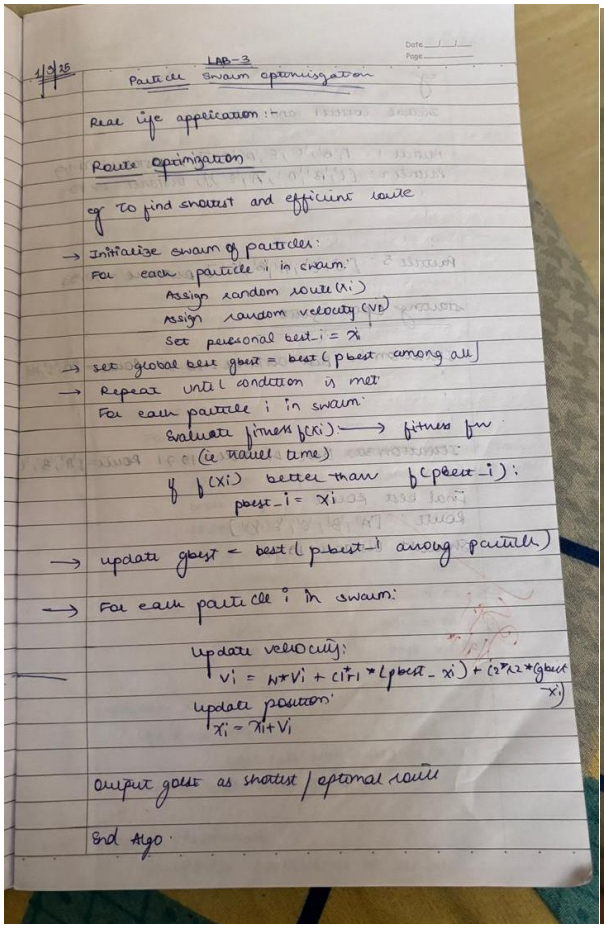
```
import random
import math

# Step 1: Define the problem
def distance(city1, city2):
    return math.sqrt((city1[0] - city2[0])**2 + (city1[1] - city2[1])**2)

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

# Step 2: Parameters
POP_SIZE = 50
N_GENES = 6
N_GENERATIONS = 100
MUT_RATE = 0.2
CROSS_RATE = 0.7

# Step 3: Cities (coordinates)
cities = [(random.randint(0, 100), random.randint(0, 100)) for _ in range(N_GENES)]

# Step 4: Initialize population (random tours)
def create_individual():
    tour = list(range(N_GENES))
    random.shuffle(tour)
    return tour

population = [create_individual() for _ in range(POP_SIZE)]

# Step 5: Evaluate fitness
def fitness(ind):
    return 1 / (1 + tour_length(ind, cities))

# Step 6: Selection (roulette wheel)
def selection(pop):
    weights = [fitness(ind) for ind in pop]
    return random.choices(pop, weights=weights, k=2)

# Step 7: Crossover (Order Crossover for TSP)
def crossover(parent1, parent2):
    if random.random() > CROSS_RATE:
        return parent1[:]
    start, end = sorted(random.sample(range(N_GENES), 2))
    child = [None]*N_GENES
    child[start:end] = parent1[start:end]
```

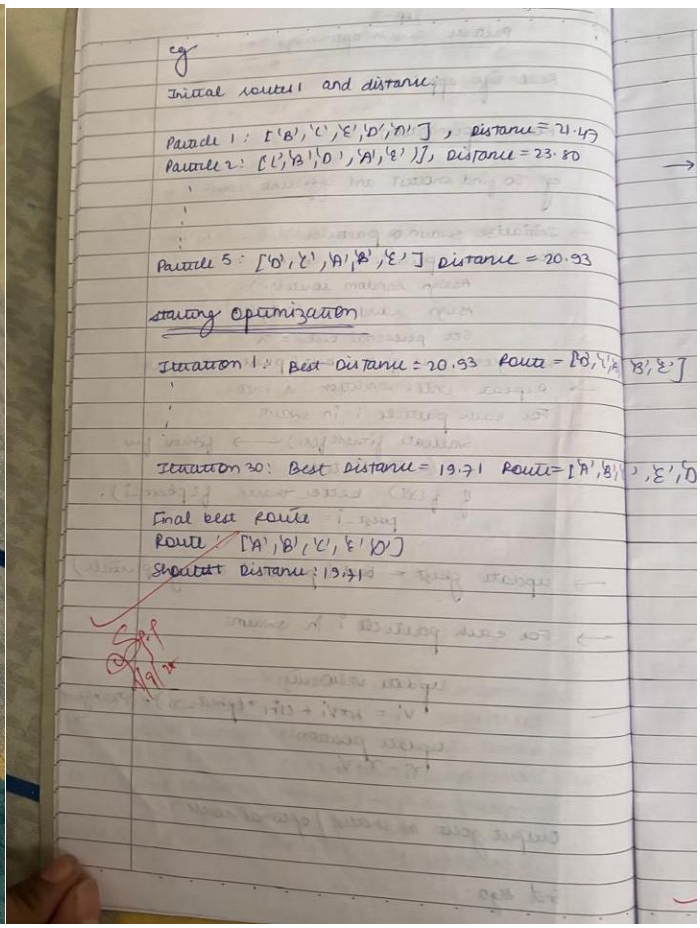
```
    pos = end
    for gene in parent2:
        if gene not in child:
            if pos >= N_GENES: pos = 0
            child[pos] = gene
            pos += 1
    return child

# Step 8: Mutation (swap two cities)
def mutate(ind):
    if random.random() < MUT_RATE:
        i, j = random.sample(range(N_GENES), 2)
        ind[i], ind[j] = ind[j], ind[i]

# Step 9: Gene Expression Algorithm loop
best = None
for gen in range(N_GENERATIONS):
    new_population = []
    for _ in range(POP_SIZE):
        p1, p2 = selection(population)
        child = crossover(p1, p2)
        mutate(child)
        new_population.append(child)
    population = new_population

    # Track best solution
    current_best = min(population, key=lambda ind: tour_length(ind, cities))
    if best is None or tour_length(current_best, cities) < tour_length(best, cities):
        best = current_best

# Step 10: Output best solution
print("Cities (coordinates):")
for i, c in enumerate(cities):
    print(f"City {i}: {c}")

print("\nBest tour order (by city indices):", best)
print("Best tour length:", tour_length(best, cities))

print("\nBest tour path (with coordinates):")
for idx in best:
    print(f"City {idx} -> {cities[idx]}")
print(f"Back to start -> {cities[best[0]]}")
```

Program 3

Implement Particle Swarm Optimization (PSO) to find the minimum of a simple two-dimensional objective function: f(x, y) = x^2 + y^2.

Algorithm:





Code:

```
import numpy as np

# Objective function
def f(position):
    x, y = position
    return x**2 + y**2

# Parameters
w = 0.5       # inertia weight
c1 = 1.5      # cognitive coefficient
c2 = 1.5      # social coefficient
```

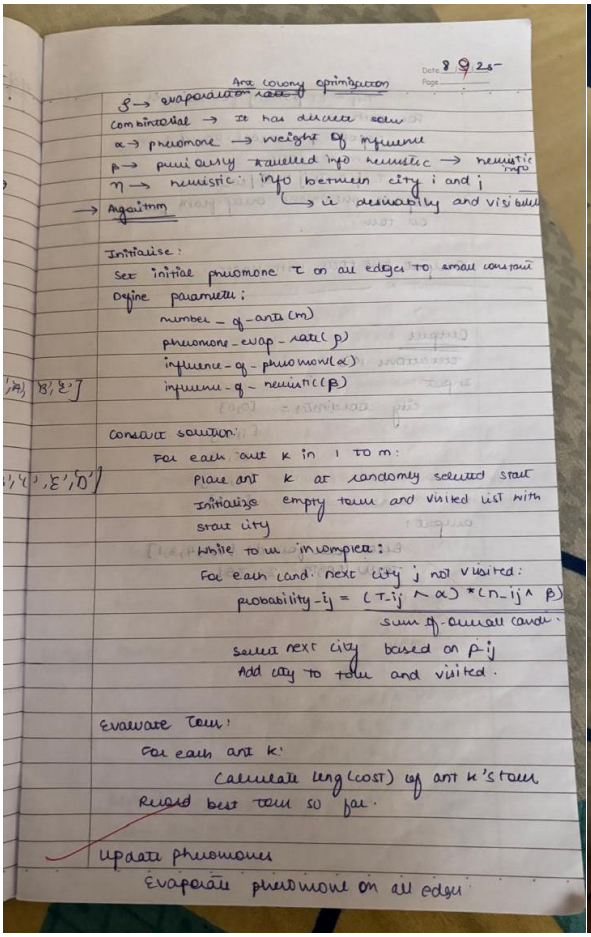
```
num_particles = 3
num_iterations = 2
dim = 2       # dimensions: x and y

# Initialize particles' positions and velocities (as per example)
positions = np.array([[2.0, 2.0],
                      [-3.0, -1.0],
                      [1.0, -4.0]])

velocities = np.zeros((num_particles, dim))

personal_best_positions = positions.copy()
personal_best_values = np.array([f(pos) for pos in positions])

# Initialize global best
best_idx = np.argmin(personal_best_values)
global_best_position = personal_best_positions[best_idx].copy()
global_best_value = personal_best_values[best_idx]

print(f"Initial global best: position={global_best_position}, value={global_best_value}\n")

for iter in range(1, num_iterations + 1):
   print(f"Iteration {iter}:")

   for i in range(num_particles):
      r1, r2 = np.random.rand(2)

      # Update velocity
      cognitive = c1 * r1 * (personal_best_positions[i] - positions[i])
      social = c2 * r2 * (global_best_position - positions[i])
      velocities[i] = w * velocities[i] + cognitive + social

      positions[i] = positions[i] + velocities[i]

      fitness = f(positions[i])

      if fitness < personal_best_values[i]:
         personal_best_values[i] = fitness
         personal_best_positions[i] = positions[i].copy()

   best_idx = np.argmin(personal_best_values)
   if personal_best_values[best_idx] < global_best_value:
      global_best_value = personal_best_values[best_idx]
      global_best_position = personal_best_positions[best_idx].copy()

   for i in range(num_particles):
      print(f" Particle {i+1}: position={positions[i]}, velocity={velocities[i]},
fitness={f(positions[i])}")
```

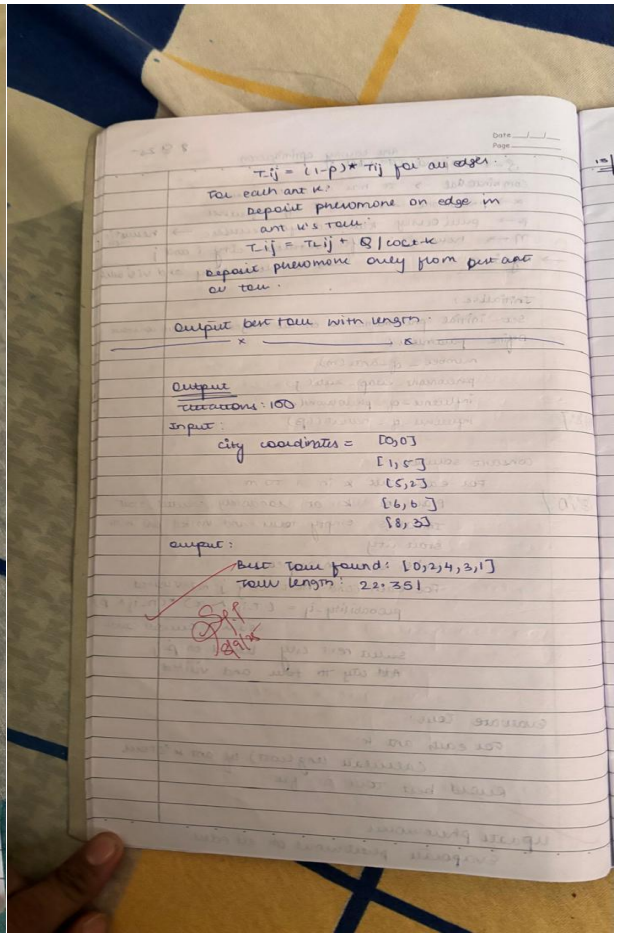
```
print(f" Global best position: {global_best_position}, value: {global_best_value}\n")
```

Program 4

To find the shortest route visiting all the cities exactly once and returning to start, using Ant Colony Optimisation algorithm.

Algorithm:





Code:

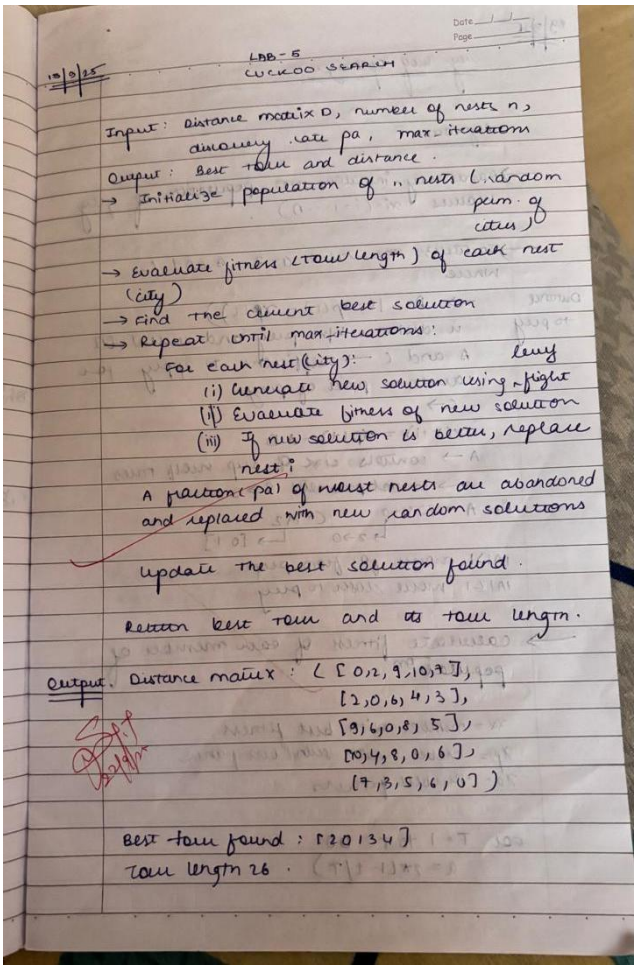
```
import numpy as np
import random

class ACO_TSP:
    def __init__(self, distances, n_ants=10, n_iterations=100, alpha=1.0, beta=5.0, rho=0.5, Q=100):
        self.distances = distances
        self.n_cities = len(distances)
        self.n_ants = n_ants
        self.n_iterations = n_iterations
        self.alpha = alpha
        self.beta = beta
        self.rho = rho
        self.Q = Q
        self.pheromone = np.ones((self.n_cities, self.n_cities))  # initial pheromone

        self.heuristic = 1 / (distances + np.eye(self.n_cities))  # avoid divide-by-zero on diagonal
        np.fill_diagonal(self.heuristic, 0)

    def run(self):
        best_length = float('inf')
        best_tour = []

        for _ in range(self.n_iterations):
            all_tours = []
            all_lengths = []

            for _ in range(self.n_ants):
                tour = self.construct_solution()
                length = self.tour_length(tour)
                all_tours.append(tour)
                all_lengths.append(length)

                if length < best_length:
                    best_length = length
                    best_tour = tour

            self.update_pheromones(all_tours, all_lengths)

        return best_tour, best_length

    def construct_solution(self):
        tour = []
        visited = set()
        current_city = random.randint(0, self.n_cities - 1)
        tour.append(current_city)
        visited.add(current_city)
```

```
        while len(tour) < self.n_cities:
            probs = []
            for city in range(self.n_cities):
                if city not in visited:
                    pher = self.pheromone[current_city][city] ** self.alpha
                    heur = self.heuristic[current_city][city] ** self.beta
                    probs.append((city, pher * heur))
            total = sum(p for _, p in probs)
            r = random.uniform(0, total)
            s = 0
            for city, p in probs:
                s += p
                if s >= r:
                    next_city = city
                    break
            tour.append(next_city)
            visited.add(next_city)
            current_city = next_city

        return tour

    def tour_length(self, tour):
        return sum(self.distances[tour[i]][tour[(i + 1) % self.n_cities]] for i in range(self.n_cities))

    def update_pheromones(self, all_tours, all_lengths):
        self.pheromone *= (1 - self.rho)  # Evaporation
        for tour, length in zip(all_tours, all_lengths):
            for i in range(len(tour)):
                a = tour[i]
                b = tour[(i + 1) % len(tour)]
                self.pheromone[a][b] += self.Q / length
                self.pheromone[b][a] += self.Q / length  # symmetric

# Example usage:
if __name__ == "__main__":
    distance_matrix = np.array([
        [0, 2, 9, 10],
        [1, 0, 6, 4],
        [15, 7, 0, 8],
        [6, 3, 12, 0]
    ])

    aco = ACO_TSP(distance_matrix, n_ants=10, n_iterations=100)
    best_tour, best_length = aco.run()
    print("Best Tour:", best_tour)
    print("Best Length:", best_length)
```

Program 5

To find the shortest route visiting all the cities exactly once and returning to start, using the Cuckoo Search algorithm.

Algorithm:



Code:

```
import numpy as np
import random

def tour_length(tour, dist_matrix):
    #Calculate total distance of a TSP tour.
    return sum(dist_matrix[tour[i], tour[(i+1) % len(tour)]] for i in range(len(tour)))

def levy_flight(Lambda=1.5):
    #Generate step size using Lévy distribution.
    sigma = (np.math.gamma(1+Lambda) * np.sin(np.pi*Lambda/2) /
            (np.math.gamma((1+Lambda)/2) * Lambda * 2**((Lambda-1)/2)))**(1/Lambda)
    u = np.random.normal(0, sigma)
```

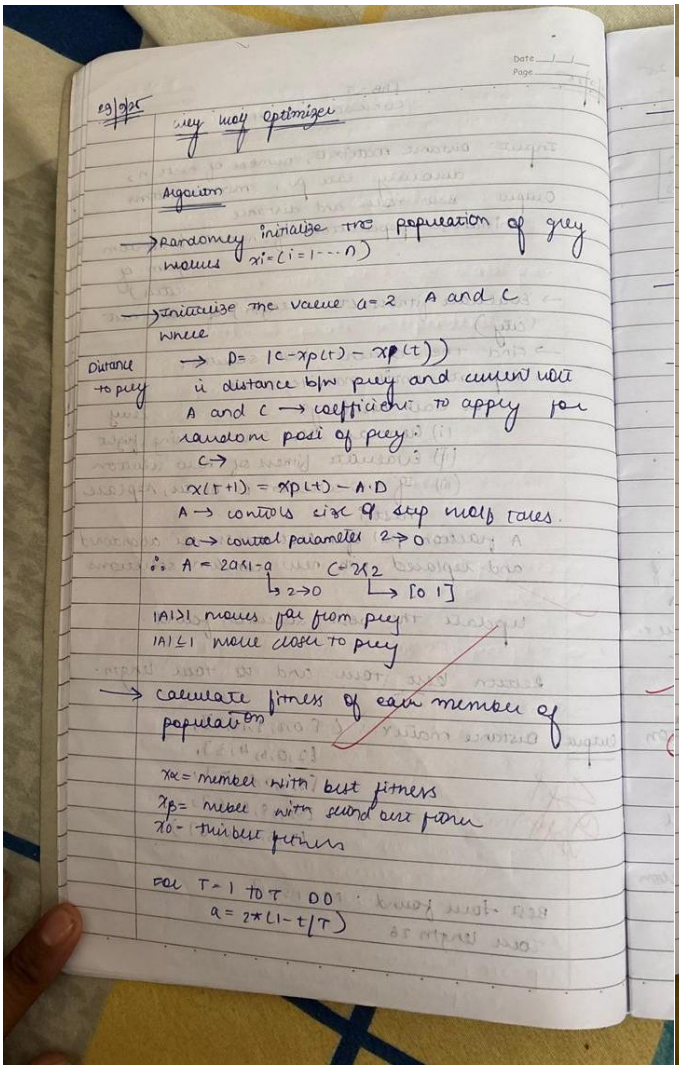
```
    v = np.random.normal(0, 1)
    step = u / abs(v)**(1/Lambda)
    return step

def cuckoo_search_tsp(dist_matrix, n=20, pa=0.25, max_iter=500):
    num_cities = len(dist_matrix)

    # Initialize nests (random tours)
    nests = [random.sample(range(num_cities), num_cities) for _ in range(n)]
    fitness = [tour_length(t, dist_matrix) for t in nests]

    best_tour = nests[np.argmin(fitness)]
    best_fit = min(fitness)

    for _ in range(max_iter):
        for i in range(n):
            # Generate new solution by applying a random swap (levy inspired)
            new_tour = nests[i][:]
            step = int(abs(levy_flight()) * num_cities) % num_cities
            if step > 1:
                a, b = random.sample(range(num_cities), 2)
                new_tour[a], new_tour[b] = new_tour[b], new_tour[a]

            new_fit = tour_length(new_tour, dist_matrix)

            # Replace if better
            if new_fit < fitness[i]:
                nests[i], fitness[i] = new_tour, new_fit

                # Update best
                if new_fit < best_fit:
                    best_tour, best_fit = new_tour, new_fit

        # Abandon some nests
        for i in range(n):
            if random.random() < pa:
                nests[i] = random.sample(range(num_cities), num_cities)
                fitness[i] = tour_length(nests[i], dist_matrix)

    return best_tour, best_fit


# Example usage
if __name__ == "__main__":
    # Distance matrix for 5 cities (symmetric TSP)
    dist_matrix = np.array([
        [0, 2, 9, 10, 7],
        [2, 0, 6, 4, 3],
        [9, 6, 0, 8, 5],
```

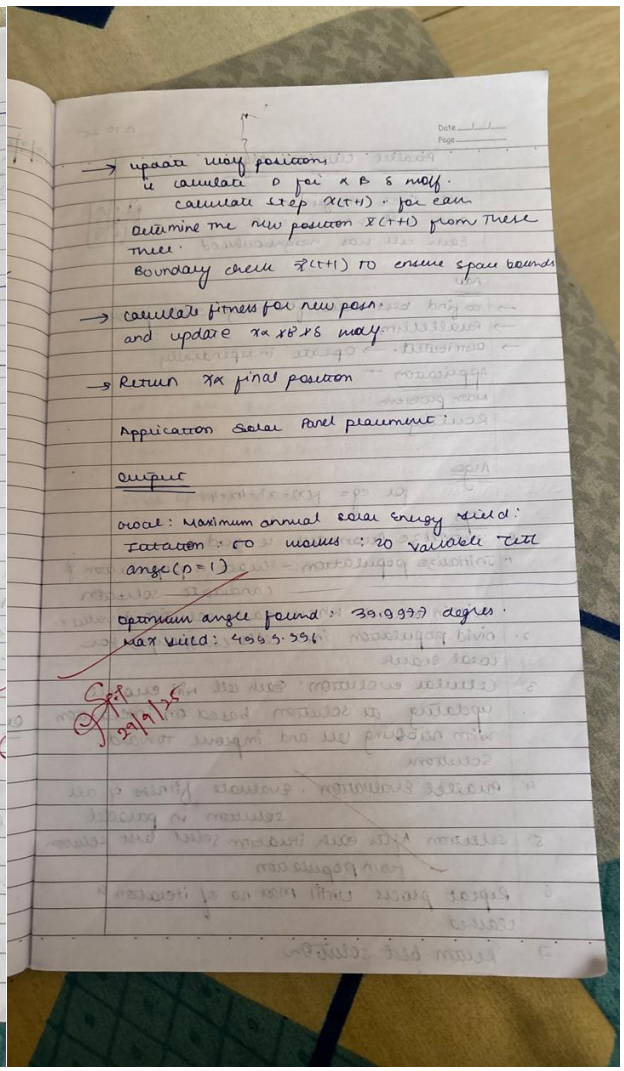
```
    [10, 4, 8, 0, 6],
    [7, 3, 5, 6, 0]
])

best_tour, best_length = cuckoo_search_tsp(dist_matrix, n=15, pa=0.3, max_iter=200)
print("Best tour found:", best_tour)
print("Tour length:", best_length)
```

Program 6

To schedule n jobs to m machines, using the Grey Wolf Optimiser algorithm.

Algorithm:





Code:

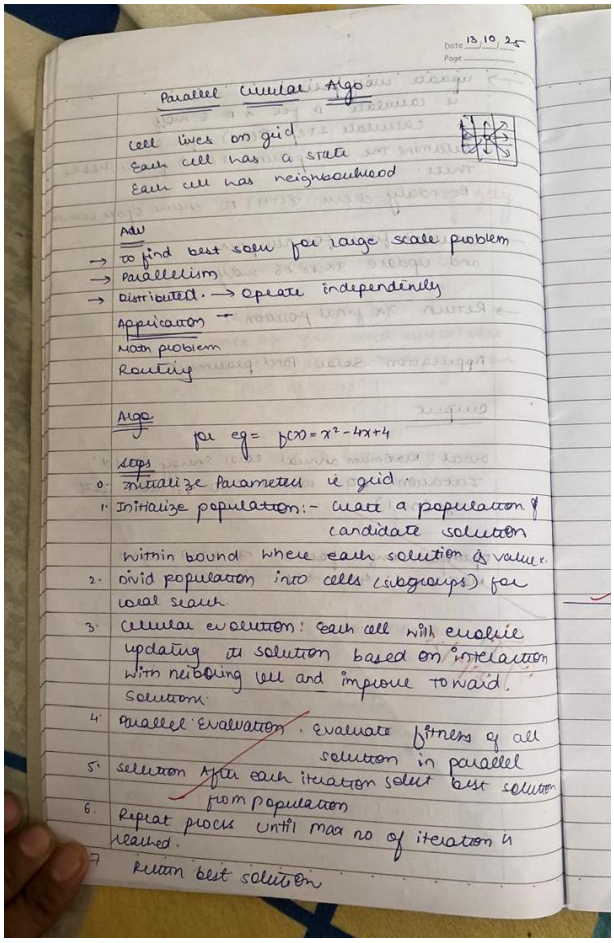
```
import numpy as np

# ---- Problem Setup ----
num_jobs = 6
num_machines = 3
jobs = np.random.randint(1, 10, size=num_jobs)  # processing times

def fitness(schedule):
    """Compute makespan for a given schedule (list of machine assignments)."""
    machine_times = [0] * num_machines
    for j, m in enumerate(schedule):
        machine_times[m] += jobs[j]
    return max(machine_times)  # makespan

# ---- GWO Algorithm ----
def gwo(max_iter=30, pack_size=10):
    # Initialize wolves (random schedules)
    wolves = [np.random.randint(0, num_machines, size=num_jobs) for _ in range(pack_size)]
    fitness_vals = [fitness(w) for w in wolves]

    # Identify alpha, beta, delta
    alpha, beta, delta = np.argsort(fitness_vals)[:3]
    alpha_wolf, beta_wolf, delta_wolf = wolves[alpha], wolves[beta], wolves[delta]

    for t in range(max_iter):
        a = 2 - 2 * (t / max_iter)  # linearly decreasing

        for i in range(pack_size):
            X = wolves[i].copy().astype(float)

            for j in range(num_jobs):
                r1, r2 = np.random.rand(), np.random.rand()

                # Distances from alpha, beta, delta
                A1, C1 = 2*a*r1 - a, 2*r2
                D_alpha = abs(C1*alpha_wolf[j] - X[j])
                X1 = alpha_wolf[j] - A1*D_alpha

                r1, r2 = np.random.rand(), np.random.rand()
                A2, C2 = 2*a*r1 - a, 2*r2
                D_beta = abs(C2*beta_wolf[j] - X[j])
                X2 = beta_wolf[j] - A2*D_beta

                r1, r2 = np.random.rand(), np.random.rand()
                A3, C3 = 2*a*r1 - a, 2*r2
                D_delta = abs(C3*delta_wolf[j] - X[j])
                X3 = delta_wolf[j] - A3*D_delta
```

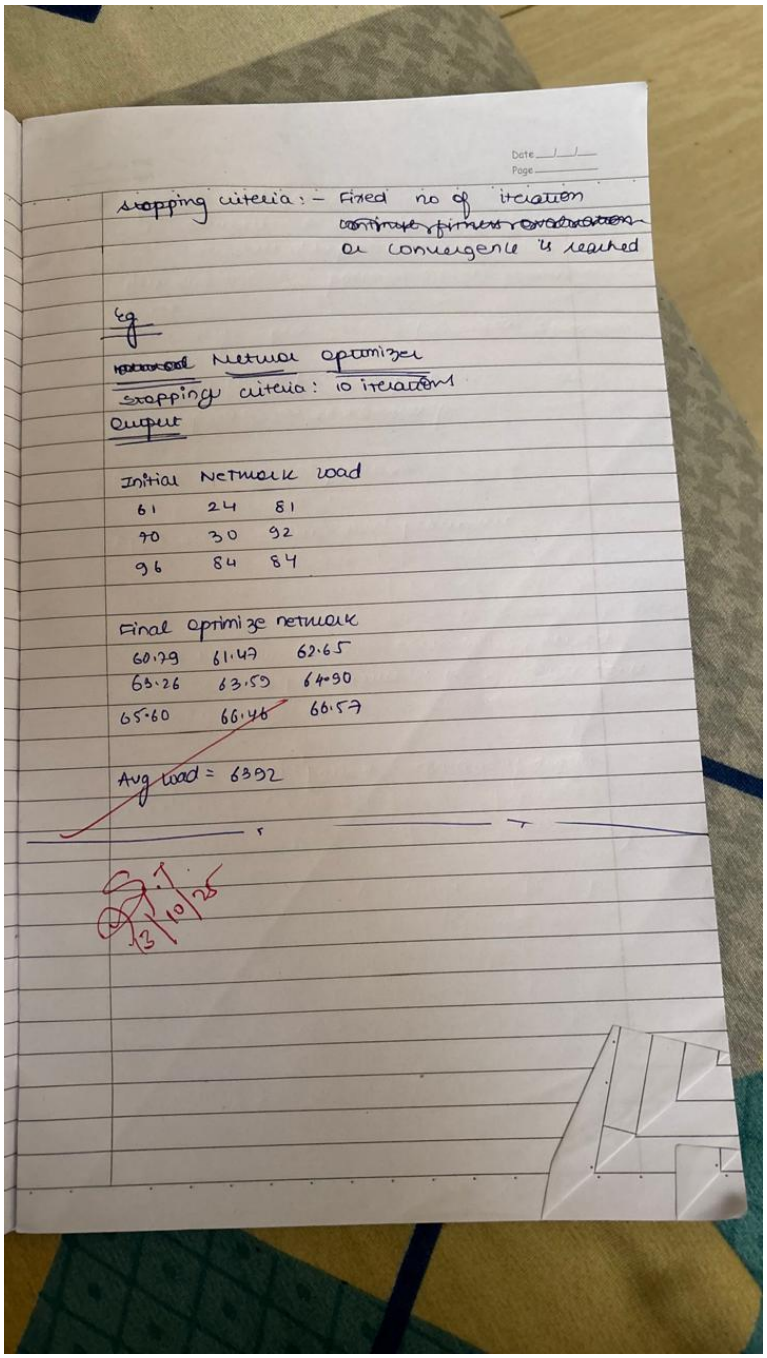
```
            X[j] = (X1 + X2 + X3) / 3

        wolves[i] = np.clip(np.round(X), 0, num_machines-1).astype(int)

    # Re-evaluate fitness
    fitness_vals = [fitness(w) for w in wolves]
    alpha, beta, delta = np.argsort(fitness_vals)[:3]
    alpha_wolf, beta_wolf, delta_wolf = wolves[alpha], wolves[beta], wolves[delta]

  return alpha_wolf, fitness(alpha_wolf)

best_schedule, best_makespan = gwo()
print("Jobs:", jobs)
print("Best Schedule (job → machine):", best_schedule)
print("Best Makespan:", best_makespan)
```

Program 7

Implement a Parallel Cellular Algorithm to compute the shortest distance from a source cell (top-left corner) to all other cells in a 2D grid using uniform edge costs.

Algorithm:





Code:

```
import numpy as np

WIDTH, HEIGHT = 10, 10
INF = 9999

def init_grid():
    grid = np.full((HEIGHT, WIDTH), INF)
    # Source at top-left corner (0,0)
    grid[0,0] = 0
    return grid
```

```
def neighbors(y, x):
    # 4-neighborhood (up, down, left, right)
    for ny, nx in [(y-1,x), (y+1,x), (y,x-1), (y,x+1)]:
        if 0 <= ny < HEIGHT and 0 <= nx < WIDTH:
            yield ny, nx

def update_distances(grid):
    new_grid = grid.copy()
    for y in range(HEIGHT):
        for x in range(WIDTH):
            for ny, nx in neighbors(y, x):
                cost = 1  # uniform cost
                new_dist = grid[ny, nx] + cost
                if new_dist < new_grid[y, x]:
                    new_grid[y, x] = new_dist
    return new_grid

def print_grid(grid):
    for row in grid:
        print(' '.join(f'{int(x):2d}' if x != INF else '∞ ' for x in row))
    print()

# Main loop
grid = init_grid()
print("Initial distances:")
print_grid(grid)

for step in range(15):
    grid = update_distances(grid)
    print(f"After step {step+1}:")
    print_grid(grid)
```