VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB RECORD

Bio Inspired Systems (23CS5BSBIS)

Submitted by

SYED FARHAN (1BM23CS424)

in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
BENGALURU-560019
Sep-2024 to Jan-2025

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 **Syed Farhan (1BM23CS424),** 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.

Syed Akram Assistant Professor Department of CSE, BMSCE	Dr. Kavitha Sooda Professor & HOD Department of CSE, BMSCE

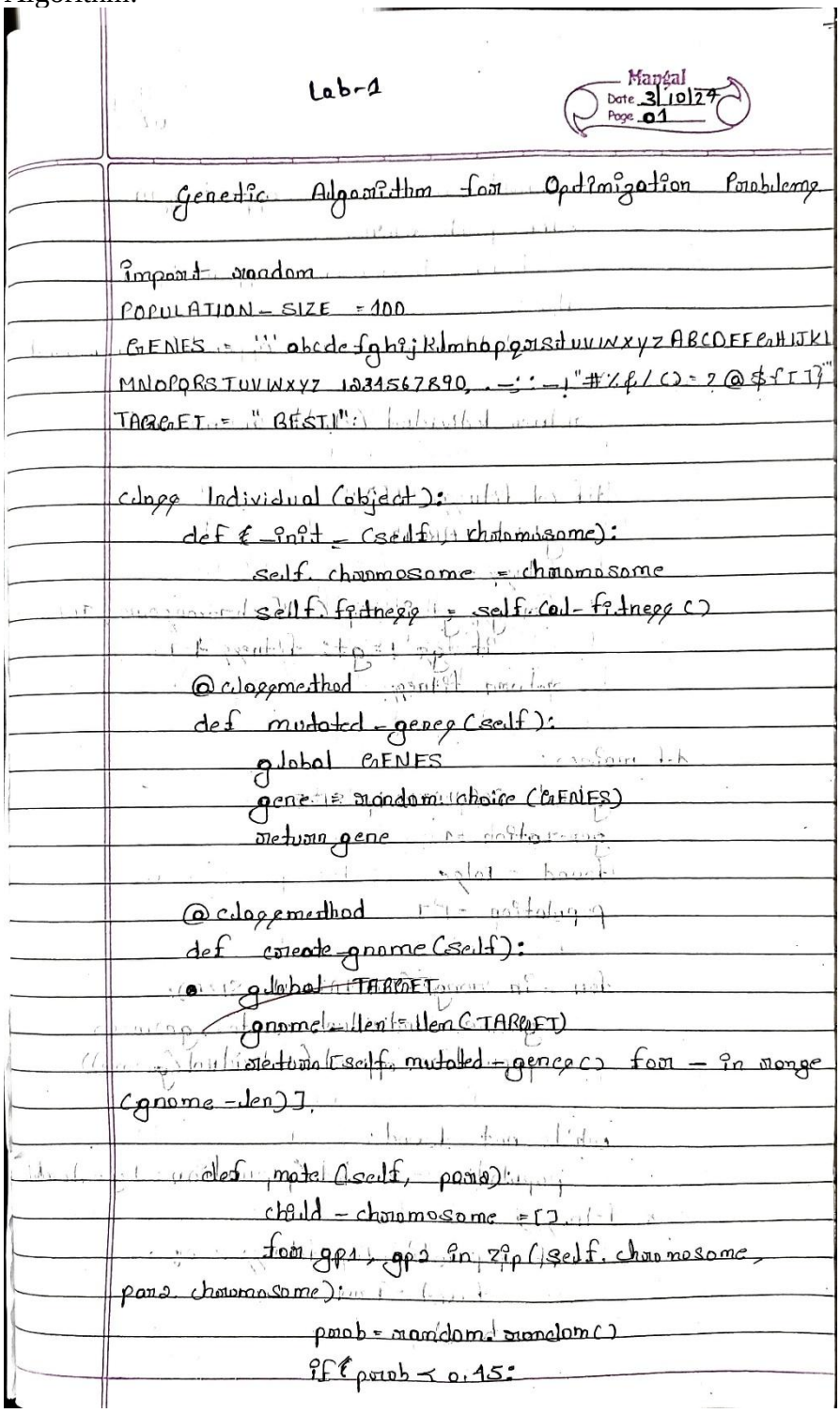
Index

Github Link: https://github.com/Syed-Farhan-bmsce/BIS.git

Program 1

Genetic Algorithm for Optimization Problems

Algorithm:



Lab-1

Mangal
Date 3/10/24
Page 01

Genetic Algorithm for Optimization Problems

```
import random
POPULATION_SIZE = 100
GENES = ''' abcdefghijklmnopqrstuvwxyzABCDEFGHIJKL
MNOPQRSTUVWXYZ 1234567890, .-;:_!"#%&/()=?@${[]}'''
TARGET = "BEST"

class Individual(object):
    def __init__(self, chromosome):
        self.chromosome = chromosome
        self.fitness = self.cal_fitness()

    @classmethod
    def mutated_genes(self):
        global GENES
        gene = random.choice(GENES)
        return gene

    @classmethod
    def create_gnome(self):
        global TARGET
        gnome_len = len(TARGET)
        return [self.mutated_genes() for _ in range
(gnome_len)]

    def mate(self, par2):
        child_chromosome = []
        for gp1, gp2 in zip(self.chromosome,
par2.chromosome):
            prob = random.random()
            if prob < 0.45:
```

```
            child = chromosome.append(gp1)
        elif prob < 0.90:
            child = chromosome.append(gp2)
        else:
            child = chromosome.append(self.mutated_
genes())
        return Individual(child_chromosome)

    def cal_fitness(self):
        global TARGET
        fitness = 0
        for gs, gt in zip(self.chromosome, TARGET):
            if gs != gt: fitness += 1
        return fitness

def main():
    global POPULATION_SIZE
    generation = 1
    found = False
    population = []

    for _ in range(POPULATION_SIZE):
        gnome = Individual.create_gnome()
        population.append(Individual(gnome))

    while not found:
        population = sorted(population, key = lambda
x: x.fitness)
        if population[0].fitness <= 0:
            found = True
            break
```

```
        new_generation = []
        s = int ((10 * POPULATION_SIZE / 100)
        new_generation.extended (population[:s])
        s = int (90 * POPULATION_SIZE) / 100)
        for _ in range(s):
            parent1 = random.choice(population[:50])
            parent2 = random.choice(population[:50])
            child = parent1.mate(parent2)
            new_generation.append(child)

        population = new_generation

        print("Generation: %2d\t String: %s\t Fitness: %2d"%(generation, "".join(population[0].chromosome)
                population[0].fitness))
        generation += 1

        print("Generation: %2d\t String: %s\t Fitness: %2d", format(generation, "".join(population[0].chromosome), population[0].fitness))

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

Output:

```
gen: 1  Str: BR6CP   fitness: 3
gen: 2  Str: BR6CP   fitness: 3
gen: 3  Str: BR6CP   fitness: 3
gen: 4  Str: G9SCE   fitness: 2
gen: 5  Str: G9SCE   fitness: 2
gen: 6  Str: B#SCE   fitness: 1
gen: 7  Str: B#SCE   fitness: 1
gen: 8  Str: B#SCE   fitness: 1
gen: 9  Str: BMSCE   fitness: 0
```

Code:

```
import random

POPULATION_SIZE = 100

GENES = '''abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOP
QRSTUVWXYZ 1234567890, .-;:_!"#%&/()=?@${[]}'''

TARGET = "I love GeeksforGeeks"

class Individual(object):
    '''
    Class representing individual in population
    '''
    def __init__(self, chromosome):
        self.chromosome = chromosome
        self.fitness = self.cal_fitness()

    @classmethod
    def mutated_genes(self):
        '''
        create random genes for mutation
        '''
        global GENES
        gene = random.choice(GENES)
        return gene

    @classmethod
    def create_gnome(self):
        '''
        create chromosome or string of genes
        '''
        global TARGET
        gnome_len = len(TARGET)
        return [self.mutated_genes() for _ in range(gnome_len)]

    def mate(self, par2):
        '''
        Perform mating and produce new offspring
        '''

        child_chromosome = []
        for gp1, gp2 in zip(self.chromosome, par2.chromosome):

            prob = random.random()

            if prob < 0.45:
```

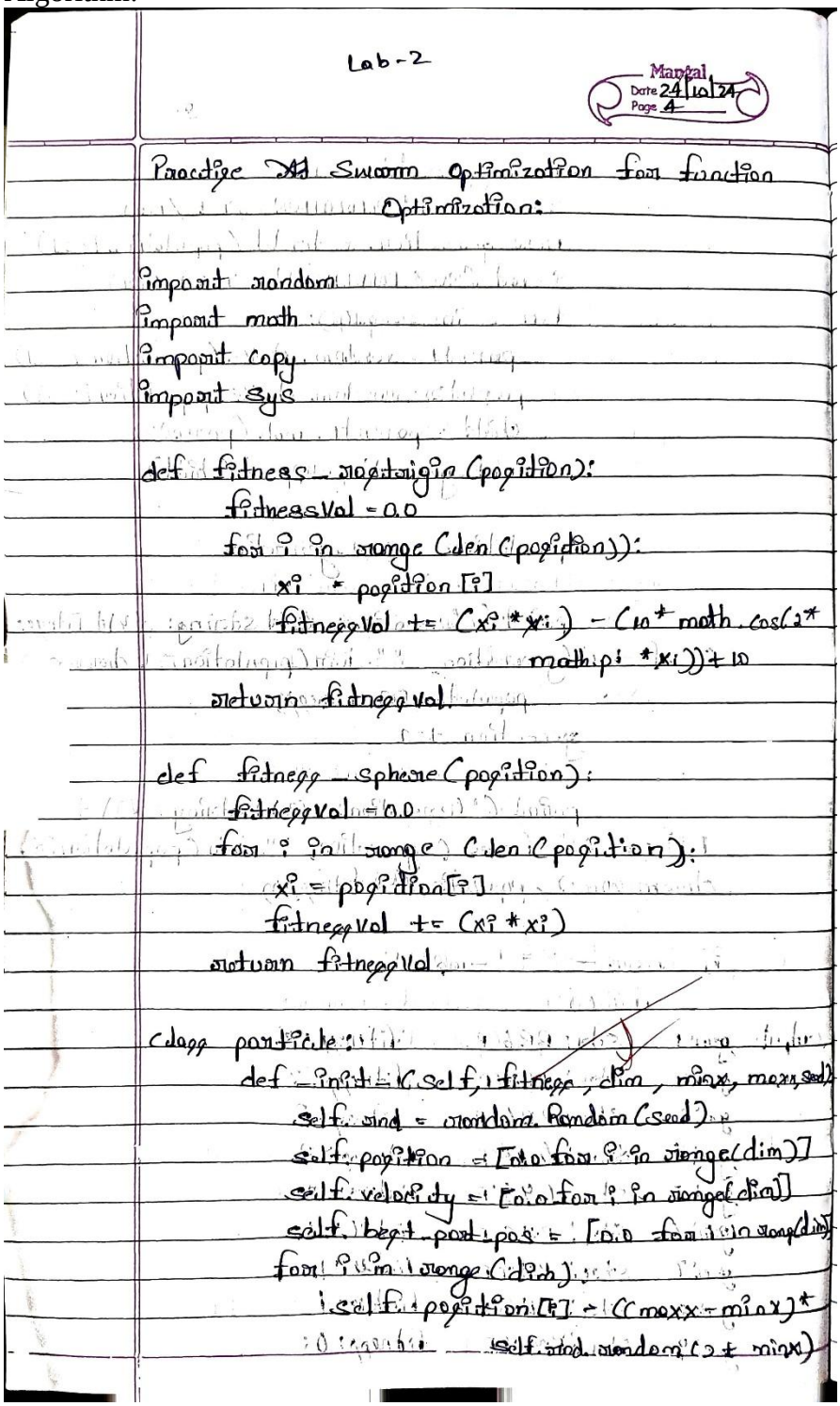
```
                        child_chromosome.append(gp1)

                    elif prob < 0.90:
                        child_chromosome.append(gp2)

                    else:
                        child_chromosome.append(self.mutated_genes())

                return Individual(child_chromosome)

        def cal_fitness(self):
                '''
                Calculate fitness score, it is the number of
                characters in string which differ from target
                string.
                '''
                global TARGET
                fitness = 0
                for gs, gt in zip(self.chromosome, TARGET):
                        if gs != gt: fitness+= 1
                return fitness

def main():
        global POPULATION_SIZE

        generation = 1

        found = False
        population = []

        for _ in range(POPULATION_SIZE):
                        gnome = Individual.create_gnome()
                        population.append(Individual(gnome))

        while not found:

                population = sorted(population, key = lambda x:x.fitness)

                if population[0].fitness <= 0:
                        found = True
                        break

                new_generation = []

                s = int((10*POPULATION_SIZE)/100)
                new_generation.extend(population[:s])
```

```
            s = int((90*POPULATION_SIZE)/100)
            for _ in range(s):
                parent1 = random.choice(population[:50])
                parent2 = random.choice(population[:50])
                child = parent1.mate(parent2)
                new_generation.append(child)

            population = new_generation

            print("Generation: {}\tString: {}\tFitness: {}".
                format(generation,
                "".join(population[0].chromosome),
                population[0].fitness))

            generation += 1


        print("Generation: {}\tString: {}\tFitness: {}".
            format(generation,
            "".join(population[0].chromosome),
            population[0].fitness))

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

Program 2

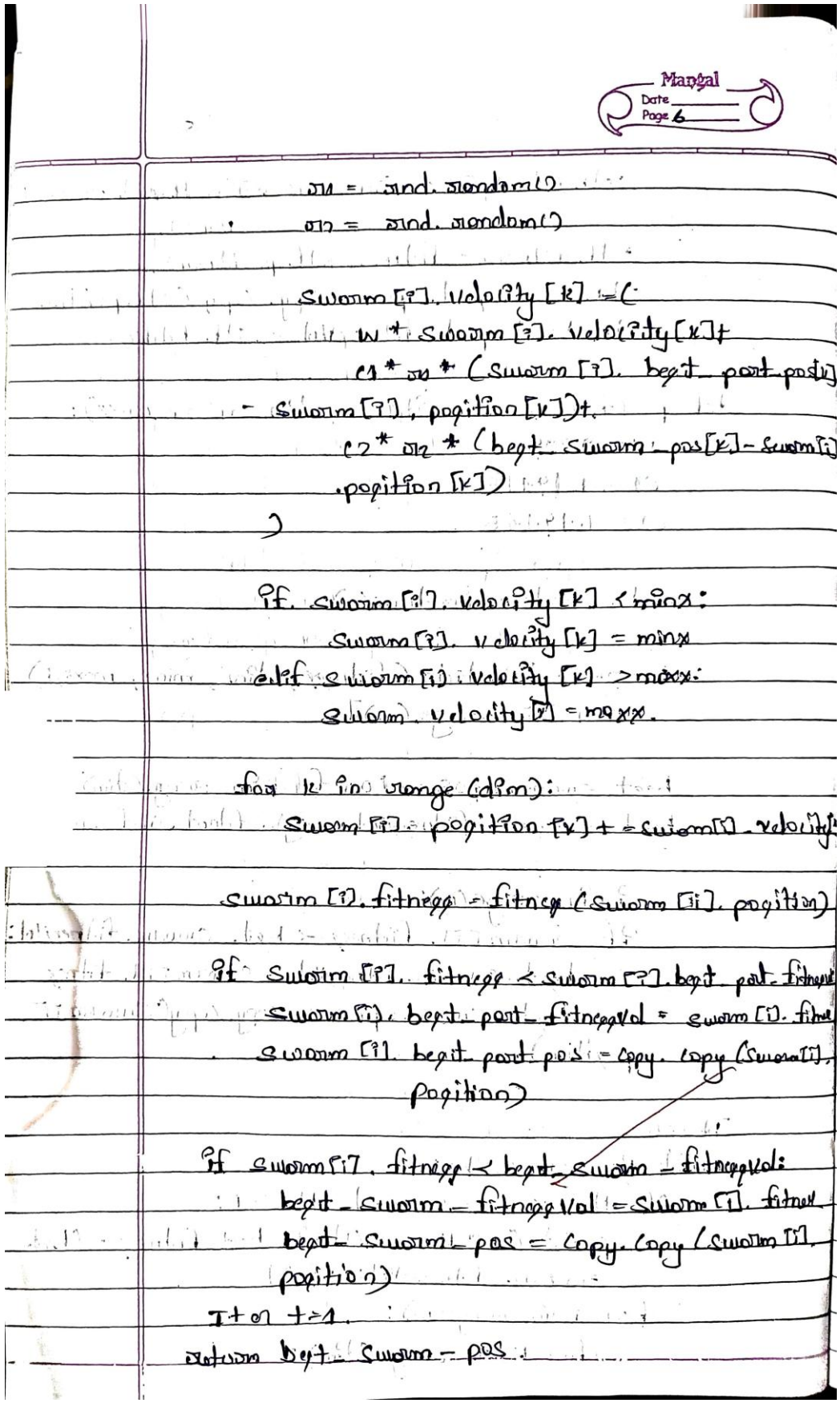
PARTICLE SWARM OPTIMIZATION

Algorithm:



```
Lab-2

Practice 24 Swarm optimization for function
          Optimization:

import random
import math
import copy
import sys

def fitness_rastrigin(position):
    fitnessVal = 0.0
    for i in range(len(position)):
        xi = position[i]
        fitnessVal += (xi*xi) - (10*math.cos(2*
                      math.pi*xi)) + 10
    return fitnessVal

def fitness_sphere(position):
    fitnessVal = 0.0
    for i in range(len(position)):
        xi = position[i]
        fitnessVal += (xi*xi)
    return fitnessVal

class particle:
    def __init__(self, fitness, dim, minx, maxx, seed):
        self.rnd = random.Random(seed)
        self.position = [0.0 for i in range(dim)]
        self.velocity = [0.0 for i in range(dim)]
        self.best_part_pos = [0.0 for i in range(dim)]
        for i in range(dim):
            self.position[i] = ((maxx - minx)*
                self.rnd.random() + minx)
```

```
        self.velocity[i] = ((maxx - minx) * self.rnd.random() +
                            minx)
        self.fitness = fitness(self.position)
        self.best_part_pos = copy.copy(self.position)
        self.best_part_fitnessVal = self.fitness

def pso(fitness, max_iter, n, dim, minx, maxx):
    w = 0.729
    c1 = 1.49445
    c2 = 1.49445

    rnd = random.Random(0)

    swarm = [Particle(fitness, dim, minx, maxx, i)
             for i in range(n)]

    best_swarm_pos = [0.0 for i in range(dim)]
    best_swarm_fitnessVal = sys.float_info.max

    for i in range(n):
        if swarm[i].fitness < best_swarm_fitnessVal:
            best_swarm_fitnessVal = swarm[i].fitness
            best_swarm_pos = copy.copy(swarm[i].
                                       position)

    Iter = 0
    while Iter < max_iter:
        if Iter % 10 == 0 and Iter > 1:
            print("Iter = " + Iter + "; best fitness = " + best_
                  swarm_fitnessVal: .3f")
        for i in range(n):
            for k in range(dim):
```


Mangal
Date
Page 6
r1 = rnd.random()
r2 = rnd.random()
swarm[i].velocity[k] = (
w * swarm[i].velocity[k] +
c1 * r1 * (swarm[i].best_part_pos[k]
- swarm[i].position[k]) +
c2 * r2 * (best_swarm_pos[k] - swarm[i]
.position[k])
)
if swarm[i].velocity[k] < minx:
swarm[i].velocity[k] = minx
elif swarm[i].velocity[k] > maxx:
swarm.velocity[k] = maxx.
for k in range(dim):
swarm[i].position[k] += swarm[i].velocity[k]
swarm[i].fitness = fitness(swarm[i].position)
if swarm[i].fitness < swarm[i].best_part_fitness:
swarm[i].best_part_fitnessVal = swarm[i].fitness
swarm[i].best_part_pos = copy.copy(swarm[i].
position)
if swarm[i].fitness < best_swarm_fitnessVal:
best_swarm_fitnessVal = swarm[i].fitness
best_swarm_pos = copy.copy(swarm[i].
position)
t+=1
return best_swarm_pos

Date
Page 7

```
print("\n Begin particle swarm optimization on Rastrigin
      function\n")
dim = 3
fitness = fitness_rastrigin
print(f" Goal is to minimize Rastrigin's function in {dim}
      variable")
print(" function has known min = 0.0 at ", end = "")
print(", ".join(["0"] * (dim - 1)) + "; 0)")

num_particles = 50
max_iter = 100

print(f" Setting num_particles = {num_particles}")
print(f" Setting max_iter = {max_iter}")
print("\n Starting PSO algorithm\n")

best_position = pso(fitness, max_iter, num_particles,
  dim, -10.0, 10.0)
print("\n PSO completed\n")
print("\n Best solution found:")
print([f" {best_position[k]:.6f}" for k in range(dim)])
fitness_val = fitness(best_position)
print(f" Fitness of best solution = {fitness_val:.6f}")
print("\n End particle swarm for Rastrigin function")

print(f" Goal is to minimize Sphere function in {dim}
  variables")
print(" function has known min = 0.0 at ", end = "")
print(", ".join(["0"] * (dim - 1)) + "; 0)")
num_particles = 50
max_iter = 100
```

```
print(f"Setting: num_particles = {num_particles}")
print(f"Setting max_iter = {max_iter}")
print("\n Starting PSO algorithm\n")

best_position = pso(fitness, max_iter, num_particle, dim,
                    -10.0, 10.0)
print("\n PSO Completed\n")
print("\n Best solution found:")
print([f"{best_position[k]:.6f}" for k in range(
    (dim))])
fitnessVal = fitness(best_position)
print(f"Fitness of best solution = {fitnessVal:.6f}")
print("\n End particle swarm for Sphere function\n")
```

O/P

Best Solution found [0.00004, -0.00001, 0.0000]
Best solution: 0.0001

Code:

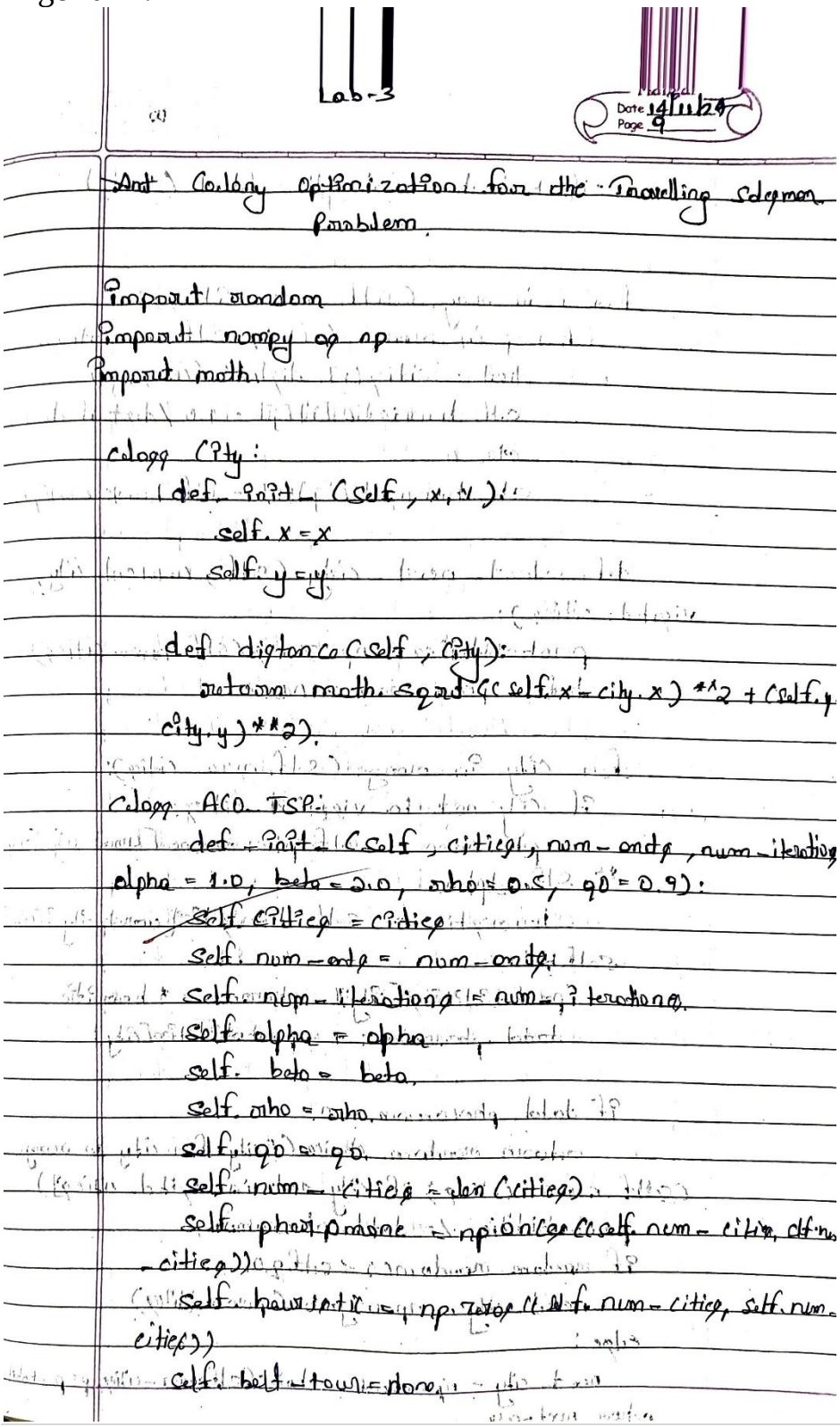
```
import random
import math
import copy
import sys

def fitness_rastrigin(position):
    return sum((xi * xi) - (10 * math.cos(2 * math.pi * xi)) + 10 for xi in position)

def fitness_sphere(position):
    return sum(xi * xi for xi in position)

class Particle:
    def __init__(self, fitness, dim, minx, maxx, seed):
        self.rnd = random.Random(seed)
        self.position = [(maxx - minx) * self.rnd.random() + minx for _ in range(dim)]
        self.velocity = [(maxx - minx) * self.rnd.random() + minx for _ in range(dim)]
        self.best_part_pos = self.position[:]
        self.fitness = fitness(self.position)
        self.best_part_fitnessVal = self.fitness

def pso(fitness, max_iter, n, dim, minx, maxx):
    w, c1, c2 = 0.729, 1.49445, 1.49445
    rnd = random.Random(0)
    swarm = [Particle(fitness, dim, minx, maxx, i) for i in range(n)]

    best_swarm_pos, best_swarm_fitnessVal = [0.0] * dim, sys.float_info.max
    for p in swarm:
        if p.fitness < best_swarm_fitnessVal:
            best_swarm_fitnessVal = p.fitness
            best_swarm_pos = p.position[:]

    for Iter in range(max_iter):
        if Iter % 10 == 0 and Iter > 1:
            print(f"Iter = {Iter} best fitness = {best_swarm_fitnessVal:.3f}")

        for p in swarm:
            for k in range(dim):
                r1, r2 = rnd.random(), rnd.random()
                p.velocity[k] = w * p.velocity[k] + c1 * r1 * (p.best_part_pos[k] - p.position[k]) + c2 * r2 *
(best_swarm_pos[k] - p.position[k])
                p.velocity[k] = max(min(p.velocity[k], maxx), minx)

            p.position = [p.position[k] + p.velocity[k] for k in range(dim)]
            p.fitness = fitness(p.position)

            if p.fitness < p.best_part_fitnessVal:
```

```
            p.best_part_fitnessVal = p.fitness
            p.best_part_pos = p.position[:]

        if p.fitness < best_swarm_fitnessVal:
            best_swarm_fitnessVal = p.fitness
            best_swarm_pos = p.position[:]

    return best_swarm_pos

def run_pso(fitness, dim, minx, maxx):
    print(f"Goal is to minimize the function in {dim} variables")
    print(f"Function has known min = 0.0 at ({', '.join(['0'] * (dim - 1))}, 0)")

    num_particles, max_iter = 50, 100
    best_position = pso(fitness, max_iter, num_particles, dim, minx, maxx)

    print(f"Best solution found: {', '.join([f'{x:.6f}' for x in best_position])}")
    print(f"Fitness of best solution = {fitness(best_position):.6f}\n")

print("\nBegin PSO for Rastrigin function\n")
run_pso(fitness_rastrigin, 3, -10.0, 10.0)

print("\nBegin PSO for Sphere function\n")
run_pso(fitness_sphere, 3, -10.0, 10.0)
```

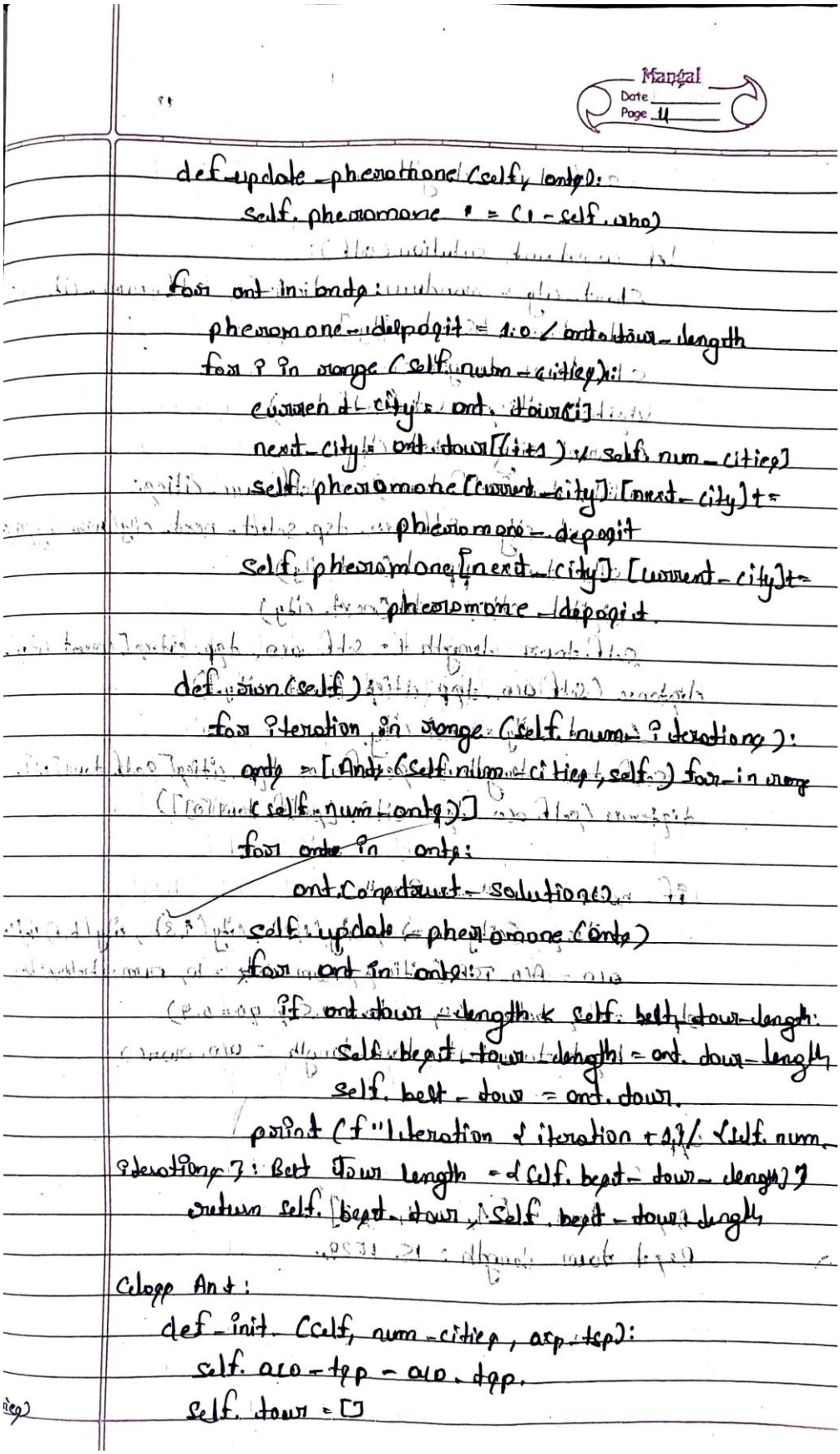
PROGRAM 3

ANT COLONY OPTIMIZATION

Algorithm:



```
        self.best_tour_length = float('inf')


    for i in range(self.num_cities):
        for j in range(i+1, self.num_cities):
            dist = cities[i].distance(cities[j])
            self.heuristic[i][j] = 1.0 / dist if dist > 0
            else 0
            self.heuristic[j][i] = self.heuristic[i][j]

    def select_next_city(self, current_city,
visited_cities):
        probabilities = np.zeros(self.num_cities)
        total_pheromone = 0.0

        for city in range(self.num_cities):
            if city not in visited_cities:
                pheromone = self.pheromone[current_city][city]
** , self.alpha
                heuristic = self.heuristic[current_city][city]
                self.beta
                probabilities[city] = pheromone * heuristic
                total_pheromone += probabilities[city]

        if total_pheromone == 0:
            return random.choice([city for city in range
(self.num_cities) if city not in visited_cities])
        probabilities /= total_pheromone
        if random.random() < self.q0:
            next_city = np.argmax(probabilities)
        else:
            next_city = np.random.choice(self.num_cities, p=probabili
```


Mangal
Date
Page 11
def update_pheromone(self, ants):
self.pheromone *= (1 - self.rho)
for ant in ants:
pheromone_deposit = 1.0 / ant.tour_length
for i in range(self.num_cities):
current_city = ant.tour[i]
next_city = ant.tour[(i+1) % self.num_cities]
self.pheromone[current_city][next_city] +=
pheromone_deposit
self.pheromone[next_city][current_city] +=
pheromone_deposit
def run(self):
for iteration in range(self.num_iterations):
ants = [Ant(self.num_cities, self) for i in range
(self.num_ants)]
for ant in ants:
ant.construct_solution()
self.update_pheromone(ants)
for ant in ants:
if ant.tour_length < self.best_tour_length:
self.best_tour_length = ant.tour_length
self.best_tour = ant.tour
print(f"Iteration {iteration + 1}/{self.num_
iterations}: Best Tour Length = {self.best_tour_length}")
return self.best_tour, self.best_tour_length
class Ant:
def __init__(self, num_cities, acp_tsp):
self.acp_tsp = acp_tsp
self.tour = []

```
        self.tour_length = 0.0

    def construct_solution(self):
        start_city = random.randint(0, self.num_cities-1)
        self.tour = [start_city]
        self.tour_length = 0.0
        visited_cities = set([start_city])
        current_city = start_city
        while len(self.tour) < self.num_cities:
            next_city = self.aco_dsp.select_next_city(current_city, visited_cities)
            self.tour.append(next_city)
            visited_cities.add(next_city)
            self.tour_length += self.aco_dsp.cities[current_city].distance(
                self.aco_dsp.cities[next_city])
            current_city = next_city
        self.tour_length += self.aco_dsp.cities[self.tour[-1]].distance(
            self.aco_dsp.cities[self.tour[0]])

    if __name__ == "__main__":
        cities = [City(0,0), City(1,3), City(4,3), City(6,1)]
        aco = ACO_TSP(cities, num_ants=10, num_iterations=100,
                      alpha=1.0, beta=2.0, rho=0.5, q0=0.9)
        best_tour, best_tour_length = aco.run()

O/p
Best tour: [2, 0, 1, 3]
Best tour length: 15.1629...
```

Code:

```
import random
import numpy as np
import math

class City:
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def distance(self, city):
        return math.sqrt((self.x - city.x)**2 + (self.y - city.y)**2)

class ACO_TSP:
    def __init__(self, cities, num_ants, num_iterations, alpha=1.0, beta=2.0, rho=0.5,
q0=0.9):
        self.cities = cities
        self.num_ants = num_ants
        self.num_iterations = num_iterations
        self.alpha = alpha
        self.beta = beta
        self.rho = rho
        self.q0 = q0
        self.num_cities = len(cities)
        self.pheromone = np.ones((self.num_cities, self.num_cities))
        self.heuristic = np.zeros((self.num_cities, self.num_cities))  (inverse of distance)
        self.best_tour = None
        self.best_tour_length = float('inf')

        for i in range(self.num_cities):
            for j in range(i + 1, self.num_cities):
                dist = cities[i].distance(cities[j])
                self.heuristic[i][j] = 1.0 / dist if dist != 0 else 0
                self.heuristic[j][i] = self.heuristic[i][j]

    def select_next_city(self, current_city, visited_cities):
        probabilities = np.zeros(self.num_cities)
        total_pheromone = 0.0

        for city in range(self.num_cities):
```

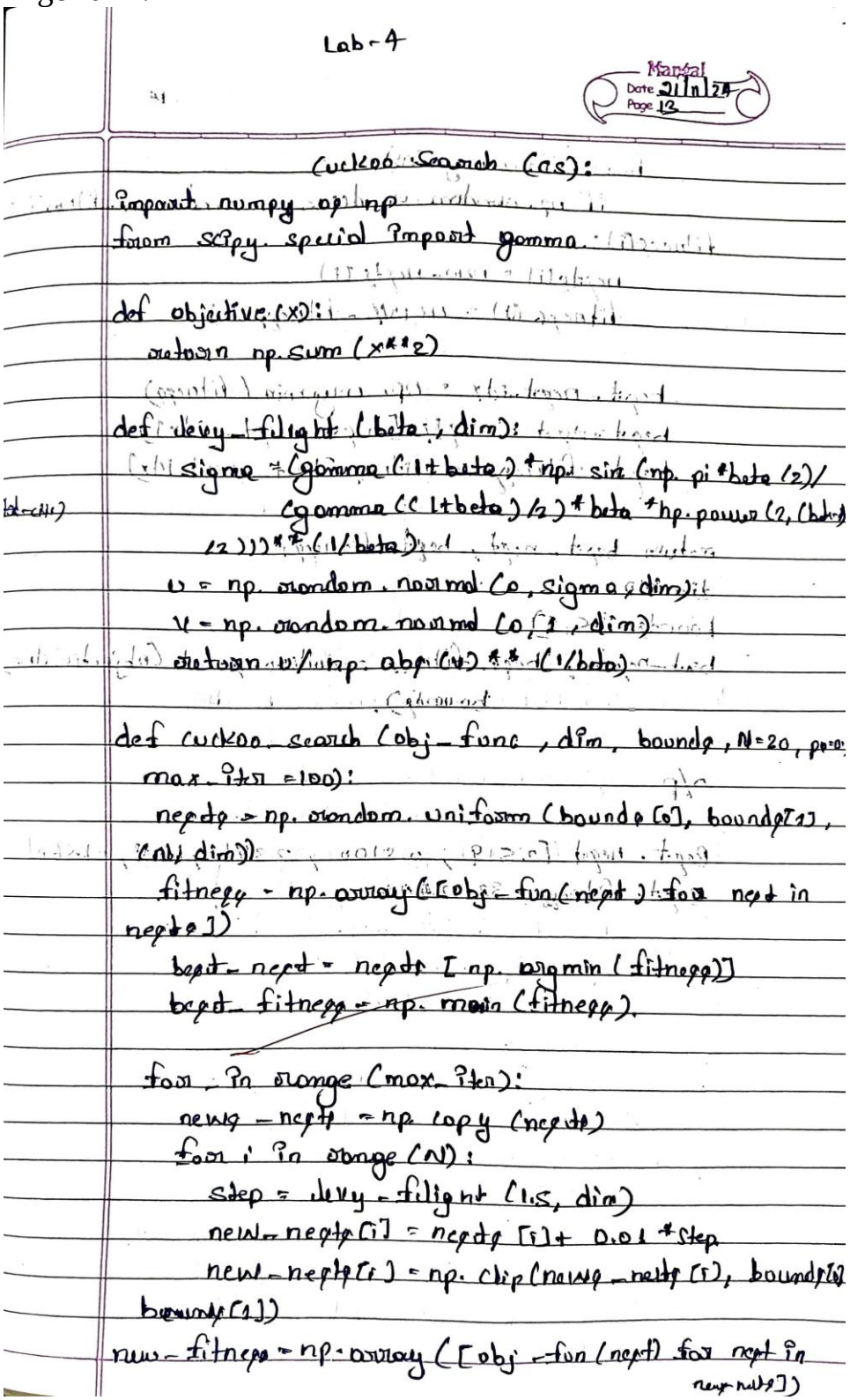
```
            if city not in visited_cities:
                pheromone = self.pheromone[current_city][city] ** self.alpha
                heuristic = self.heuristic[current_city][city] ** self.beta
                probabilities[city] = pheromone * heuristic
                total_pheromone += probabilities[city]

        if total_pheromone == 0:
            return random.choice([city for city in range(self.num_cities) if city not in
visited_cities])

        probabilities /= total_pheromone

        if random.random() < self.q0:
            next_city = np.argmax(probabilities)
        else:
            next_city = np.random.choice(self.num_cities, p=probabilities)

        return next_city

    def update_pheromone(self, ants):
        self.pheromone *= (1 - self.rho)

        for ant in ants:
            pheromone_deposit = 1.0 / ant.tour_length
            for i in range(self.num_cities):
                current_city = ant.tour[i]
                next_city = ant.tour[(i + 1) % self.num_cities]
                self.pheromone[current_city][next_city] += pheromone_deposit
                self.pheromone[next_city][current_city] += pheromone_deposit

    def run(self):
        for iteration in range(self.num_iterations):
            ants = [Ant(self.num_cities, self) for _ in range(self.num_ants)]
            for ant in ants:
                ant.construct_solution()

            self.update_pheromone(ants)


            for ant in ants:
```

```
            if ant.tour_length < self.best_tour_length:
                self.best_tour_length = ant.tour_length
                self.best_tour = ant.tour

        print(f"Iteration {iteration + 1}/{self.num_iterations}: Best Tour Length =
{self.best_tour_length}")

    return self.best_tour, self.best_tour_length

class Ant:
    def __init__(self, num_cities, aco_tsp):
        self.num_cities = num_cities
        self.aco_tsp = aco_tsp
        self.tour = []
        self.tour_length = 0.0

    def construct_solution(self):
        start_city = random.randint(0, self.num_cities - 1)
        self.tour = [start_city]
        self.tour_length = 0.0
        visited_cities = set(self.tour)
        current_city = start_city
        while len(self.tour) < self.num_cities:
            next_city = self.aco_tsp.select_next_city(current_city, visited_cities)
            self.tour.append(next_city)
            visited_cities.add(next_city)
            self.tour_length +=
self.aco_tsp.cities[current_city].distance(self.aco_tsp.cities[next_city])
            current_city = next_city
        self.tour_length += self.aco_tsp.cities[self.tour[-
1]].distance(self.aco_tsp.cities[self.tour[0]])

if __name__ == "__main__":
    cities = [City(0, 0), City(1, 3), City(4, 3), City(6, 1), City(3, 0)]
    aco = ACO_TSP(cities=cities, num_ants=10, num_iterations=100, alpha=1.0,
beta=2.0, rho=0.5, q0=0.9)
    best_tour, best_tour_length = aco.run()

    print("\nBest tour found:", best_tour)
    print("Best tour length:", best_tour_length)
```

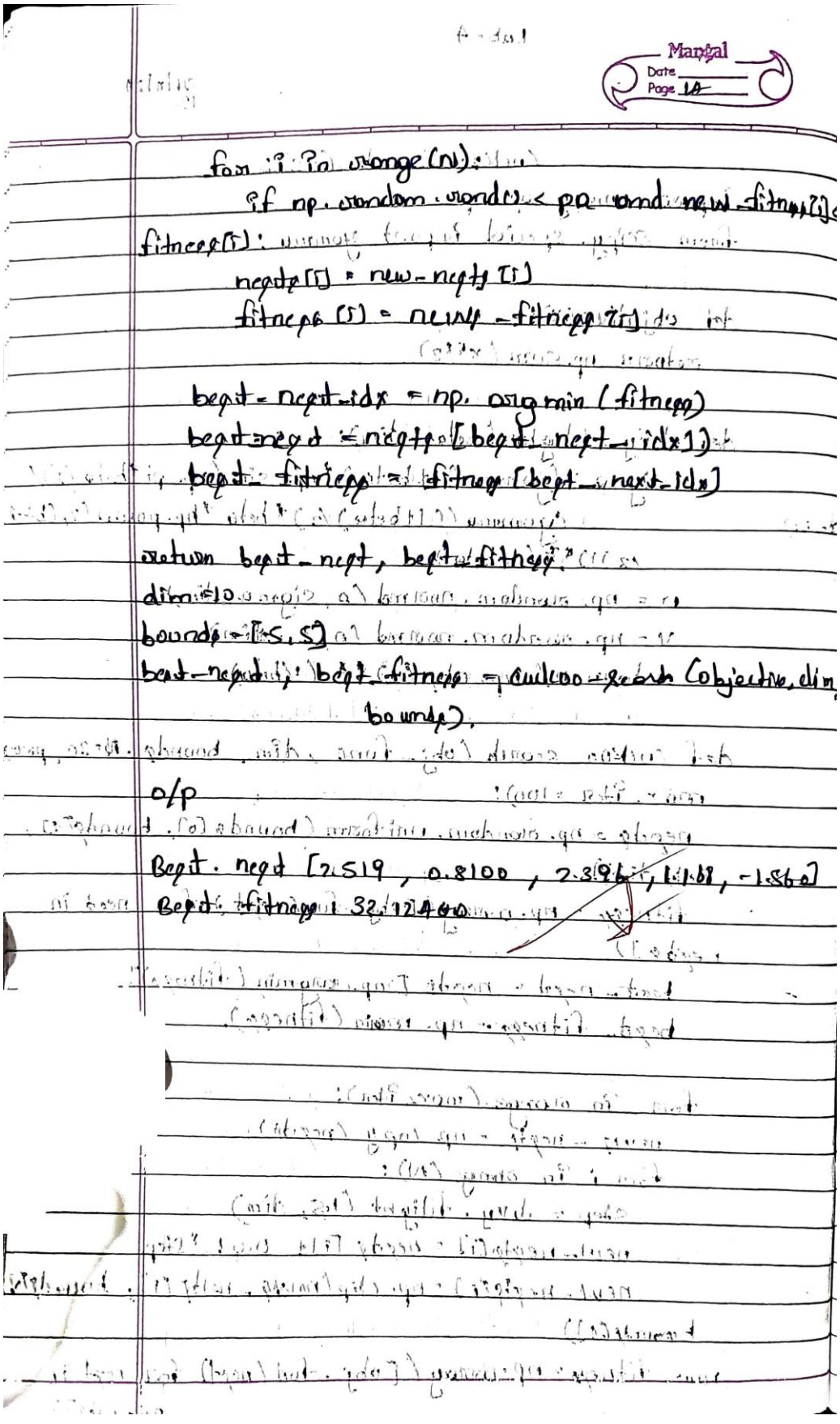
PROGRAM 4

CUCKOO SEARCH ALGORITHM

Algorithm:



```
Lab-4

Manjal
Date 21/11/24
Page 13

Cuckoo Search (cs):
import numpy as np
from scipy.special import gamma

def objective(x):
    return np.sum(x**2)

def levy_flight(beta, dim):
    sigma = (gamma(1+beta) * np.sin(np.pi*beta/2) /
             gamma((1+beta)/2) * beta * np.power(2, (beta-1)/2)))**(1/beta)
    u = np.random.normal(0, sigma, dim)
    v = np.random.normal(0, 1, dim)
    return u/np.abs(v)**(1/beta)

def cuckoo_search(obj_func, dim, bounds, N=20, pa=0.
    max_iter=100):
    nests = np.random.uniform(bounds[0], bounds[1],
    (N, dim))
    fitness = np.array([obj_fun(nest) for nest in
nests])
    best_nest = nests[np.argmin(fitness)]
    best_fitness = np.min(fitness)

    for _ in range(max_iter):
        new = nests = np.copy(nests)
        for i in range(N):
            step = levy_flight(1.5, dim)
            new_nests[i] = nests[i] + 0.01*step
            new_nests[i] = np.clip(new_nests[i], bounds[0]
        bounds[1])
    new_fitness = np.array([obj_fun(nest) for nest in
                                    new_nests])
```


Manjal
Date
Page 14
for i in range(n):
if np.random.rand() < pa and new_fitness[i]
fitness[i]:
nests[i] = new_nests[i]
fitness[i] = new_fitness[i]
best_nest_idx = np.argmin(fitness)
best_nest = nests[best_nest_idx]
best_fitness = fitness[best_nest_idx]
return best_nest, best_fitness
dim=10
bounds=[-5,5]
best_nest, best_fitness = cuckoo_search(objective, dim,
bounds),
o/p
Best. nest [2.519, 0.8100, 2.396, 1.108, -1.860]
Best. fitness: 32.12400

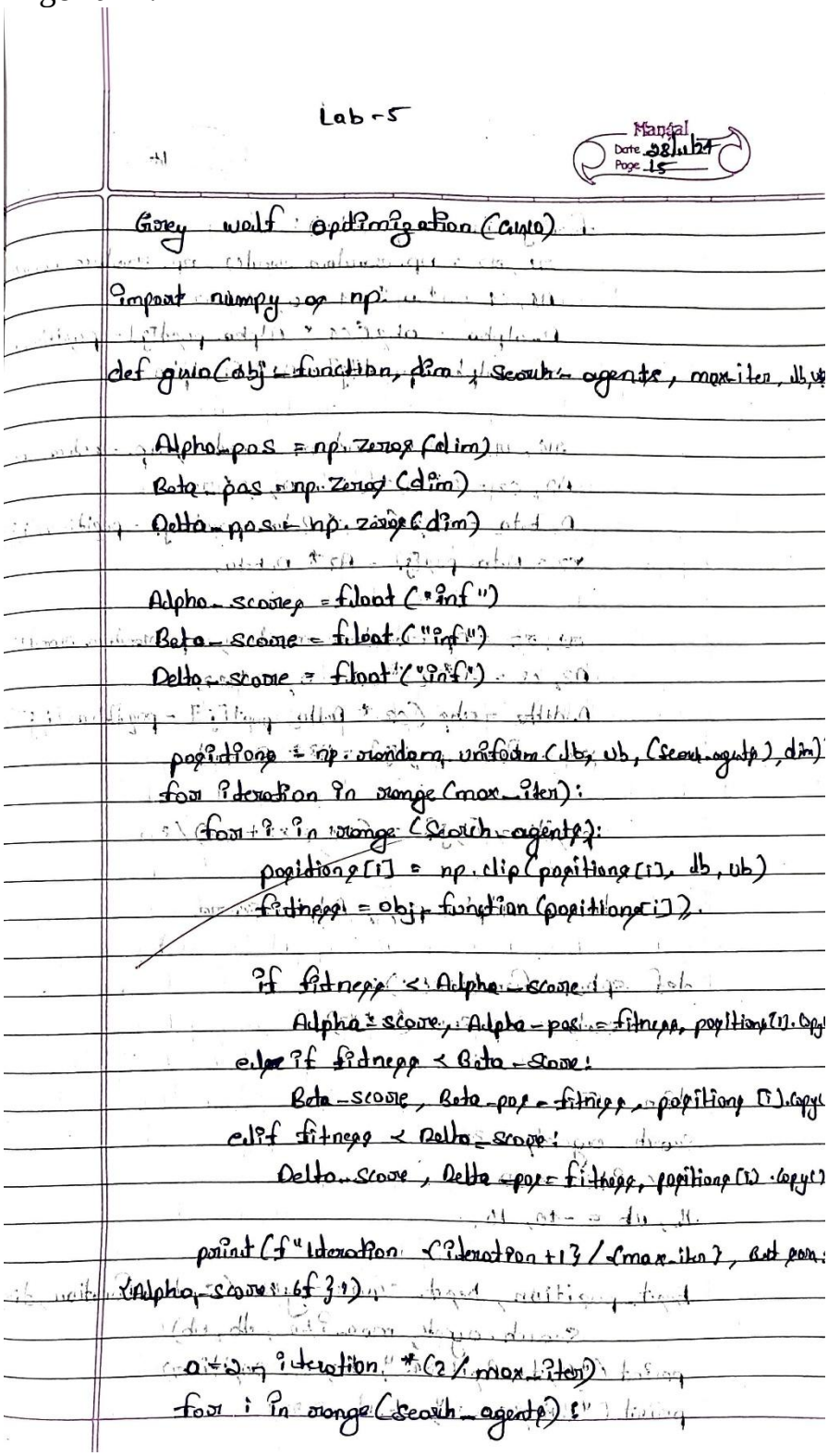
Code:

```
import numpy as np
from scipy.special import gamma

def objective(x):
    return np.sum(x**2)

def levy_flight(beta, dim):
    sigma = (gamma(1+beta)*np.sin(np.pi*beta/2) /
             (gamma((1+beta)/2)*beta*np.power(2, (beta-1)/2)))**(1/beta)
    u = np.random.normal(0, sigma, dim)
    v = np.random.normal(0, 1, dim)
    return u / np.abs(v)**(1/beta)

def cuckoo_search(obj_func, dim, bounds, N=20, pa=0.25, max_iter=100):
    nests = np.random.uniform(bounds[0], bounds[1], (N, dim))
    fitness = np.array([obj_func(nest) for nest in nests])
    best_nest = nests[np.argmin(fitness)]
    best_fitness = np.min(fitness)
    for _ in range(max_iter):
        new_nests = np.copy(nests)
        for i in range(N):
            step = levy_flight(1.5, dim)  # Lévy exponent 1.5
            new_nests[i] = nests[i] + 0.01 * step
            new_nests[i] = np.clip(new_nests[i], bounds[0], bounds[1])
        new_fitness = np.array([obj_func(nest) for nest in new_nests])
        for i in range(N):
            if np.random.rand() < pa and new_fitness[i] < fitness[i]:
                nests[i] = new_nests[i]
                fitness[i] = new_fitness[i]
        best_nest_idx = np.argmin(fitness)
        best_nest = nests[best_nest_idx]
        best_fitness = fitness[best_nest_idx]
    return best_nest, best_fitness
dim = 10
bounds = [-5, 5]
best_nest, best_fitness = cuckoo_search(objective, dim, bounds)

print(f"Best Nest: {best_nest}")
print(f"Best Fitness: {best_fitness}")
```

PROGRAM 5

GREY WOLF OPTIMIZATION

Algorithm:



```
for j in range(dim):
    r1, r2 = np.random.rand(), np.random.rand()
    A1, C1 = 2 * a * r1 - a, 2 * r2
    D_alpha = abs(C1 * Alpha_pos[j] - positions[i,j])
    X1 = Alpha_pos[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_pos[j] - positions[i,j])
    X2 = Beta_pos[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_pos[j] - positions[i,j])
    X3 = Delta_pos[j] - A3 * D_delta

    positions[i,j] = (X1 + X2 + X3) / 3
return Alpha_pos, Alpha_score

def sphere_function(x):
    return np.sum(x**2)

dim = 5
Search_agents = 30
max_iter = 50
lb, ub = -10, 10

best_position, best_score = gwo(sphere_function, dim,
        Search_agents, max_iter, lb, ub)
print("Best Position:", best_position)
print("Best Score:", best_score)
```

Mantal
Date
Page 17

o/p

Best solution : [-3.1825e-05, 3.4556-05, 3.1258-05
3.312e-05]

Best Score : 6.0726 6e-09.

Code:

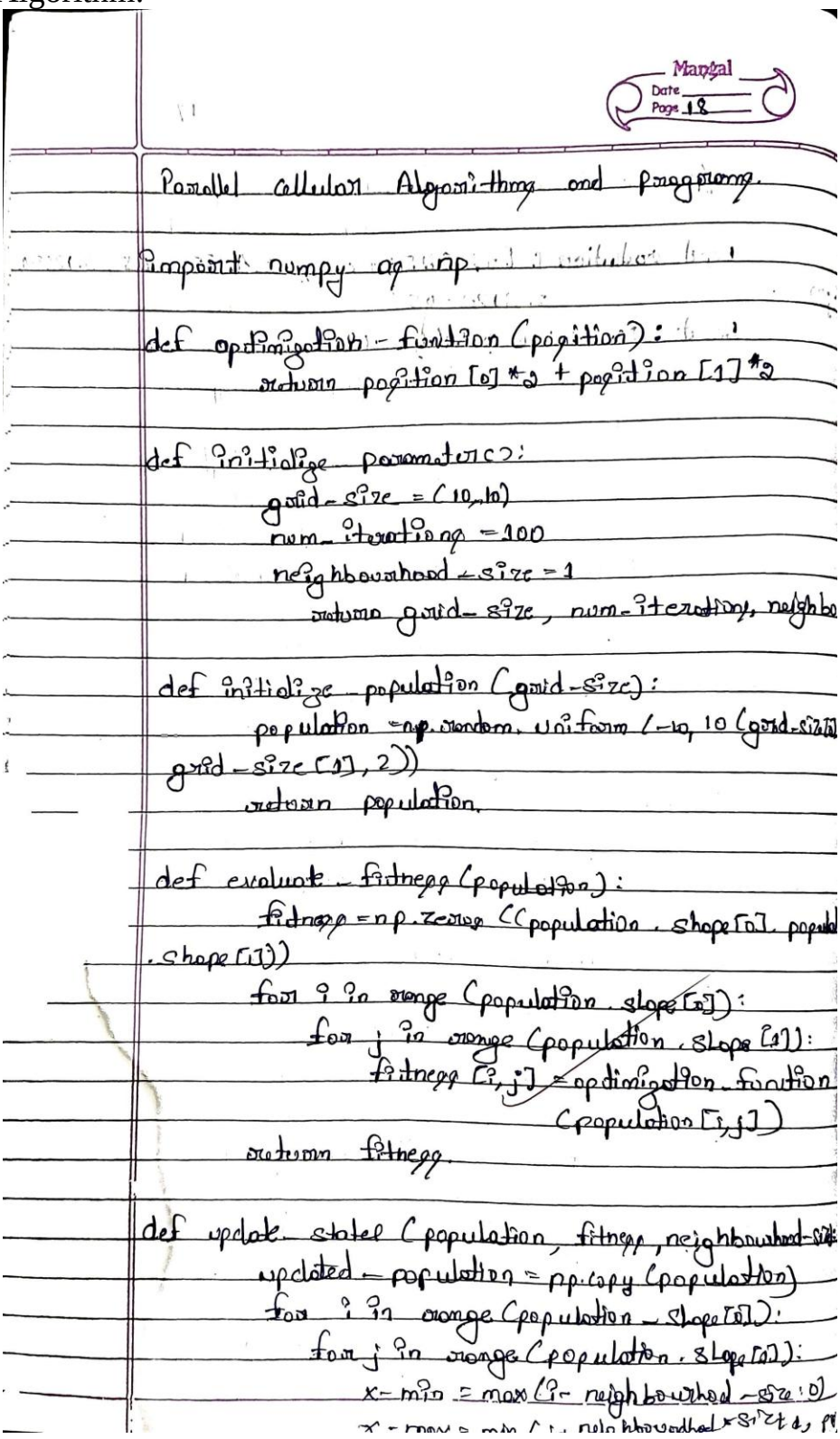
```
import numpy as np

def gwo(obj_function, dim, search_agents, max_iter, lb, ub):
    Alpha_pos = np.zeros(dim)
    Beta_pos = np.zeros(dim)
    Delta_pos = np.zeros(dim)

    Alpha_score = float("inf")
    Beta_score = float("inf")
    Delta_score = float("inf")

    positions = np.random.uniform(lb, ub, (search_agents, dim))

    for iteration in range(max_iter):
        for i in range(search_agents):
            positions[i] = np.clip(positions[i], lb, ub)

            fitness = obj_function(positions[i])

            if fitness < Alpha_score:
                Alpha_score, Alpha_pos = fitness, positions[i].copy()
            elif fitness < Beta_score:
                Beta_score, Beta_pos = fitness, positions[i].copy()
            elif fitness < Delta_score:
                Delta_score, Delta_pos = fitness, positions[i].copy()

        print(f"Iteration {iteration + 1}/{max_iter}, Best Score: {Alpha_score:.6f}")

        a = 2 - iteration * (2 / max_iter)  # Linearly decreases from 2 to 0

        for i in range(search_agents):
            for j in range(dim):
                r1, r2 = np.random.rand(), np.random.rand()

                A1, C1 = 2 * a * r1 - a, 2 * r2
                D_alpha = abs(C1 * Alpha_pos[j] - positions[i, j])
                X1 = Alpha_pos[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_pos[j] - positions[i, j])
            X2 = Beta_pos[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_pos[j] - positions[i, j])
            X3 = Delta_pos[j] - A3 * D_delta

            positions[i, j] = (X1 + X2 + X3) / 3

    return Alpha_pos, Alpha_score

def sphere_function(x):
    return np.sum(x**2)

dim = 5
search_agents = 30
max_iter = 50
lb, ub = -10, 10

best_position, best_score = gwo(sphere_function, dim, search_agents, max_iter, lb, ub)
print("Best Position:", best_position)
print("Best Score:", best_score)
```

PROGRAM 6

PARALLEL CELLULAR ALGORITHM

Algorithm:



Parallel cellular Algorithms and programs.

```
import numpy as np

def optimization_function(position):
    return position[0]**2 + position[1]**2

def initialize_parameters():
    grid_size = (10,10)
    num_iterations = 100
    neighbourhood_size = 1
    return grid_size, num_iterations, neighbo

def initialize_population(grid_size):
    population = np.random.uniform(-10, 10(grid_size[0],
grid_size[1], 2))
    return population

def evaluate_fitness(population):
    fitness = np.zeros((population.shape[0], popula
.shape[1]))
    for i in range(population.shape[0]):
        for j in range(population.shape[1]):
            fitness[i,j] = optimization_function
                (population[i,j])
    return fitness

def update_state(population, fitness, neighbourhood_si
    updated_population = np.copy(population)
    for i in range(population.shape[0]):
        for j in range(population.shape[0]):
            x_min = max(i- neighbourhood_size,0)
```

```
y_max = min(j + neighbourhood_size + 1, population.shape[1])

best_neighbour = population[i,j]
best_fitness = fitness[i,j]
for x in range(x_min, x_max):
    for y in range(y_min, y_max):
        if fitness[x,y] < best_fitness:
            best_neighbour = population[x,y]
            best_fitness = fitness[x,y]

updated_population[i,j] = (population[i,j] + best_neighbour)/2

return updated_population.

def parallel_cellular_algorithm():
    grid_size, num_iterations, neighborhood_size = initialize_parameters()
    population = initialize_population(grid_size)
    best_solution = None
    best_fitness = float('inf')

    for iteration in range(num_iterations):
        fitness = evaluate_fitness(population)
        min_fitness = np.min(fitness)
        best_fitness = min_fitness:
        best_solution = population[np.unravel_index(np.argmin(fitness), fitness.shape)].
        population = update_state(population, fitness, neighborhood_size)
```

```
    print(f"Best Solution: {best_solution}, Best
Fitness: {best_fitness}").
    return best_solution, best_fitness.

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

Output:

```
Best Solution: [-8.02149751 -7.04216626].
Best Fitness: -30.127327540600446.
```

Code:

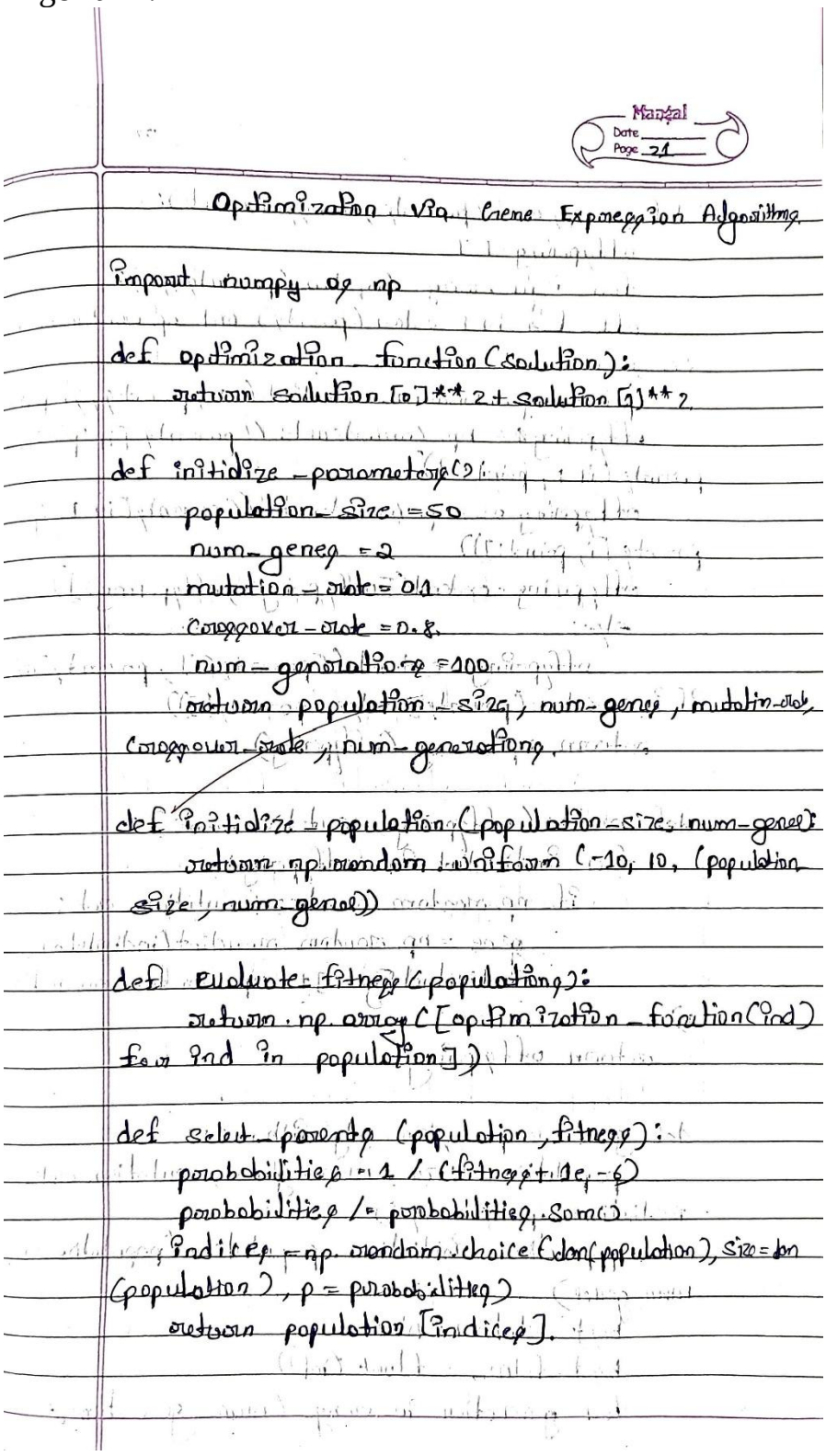
```
import numpy as np

def optimization_function(position):
    return position[0]*2 + position[1]*2

def initialize_parameters():
    grid_size = (10, 10)
    num_iterations = 100
    neighborhood_size = 1
    return grid_size, num_iterations, neighborhood_size

def initialize_population(grid_size):
    population = np.random.uniform(-10, 10, (grid_size[0], grid_size[1], 2))
    return population

def evaluate_fitness(population):
    fitness = np.zeros((population.shape[0], population.shape[1]))
    for i in range(population.shape[0]):
        for j in range(population.shape[1]):
            fitness[i, j] = optimization_function(population[i, j])
    return fitness

def update_states(population, fitness, neighborhood_size):
    updated_population = np.copy(population)
    for i in range(population.shape[0]):
        for j in range(population.shape[1]):
            x_min = max(i - neighborhood_size, 0)
            x_max = min(i + neighborhood_size + 1, population.shape[0])
            y_min = max(j - neighborhood_size, 0)
            y_max = min(j + neighborhood_size + 1, population.shape[1])

            best_neighbor = population[i, j]
            best_fitness = fitness[i, j]

            for x in range(x_min, x_max):
                for y in range(y_min, y_max):
                    if fitness[x, y] < best_fitness:
                        best_neighbor = population[x, y]
                        best_fitness = fitness[x, y]
```

```
            updated_population[i, j] = (population[i, j] + best_neighbor) / 2

    return updated_population


def parallel_cellular_algorithm():
    grid_size, num_iterations, neighborhood_size = initialize_parameters()

    population = initialize_population(grid_size)

    best_solution = None
    best_fitness = float('inf')

    for iteration in range(num_iterations):
        fitness = evaluate_fitness(population)

        min_fitness = np.min(fitness)
        if min_fitness < best_fitness:
            best_fitness = min_fitness
            best_solution = population[np.unravel_index(np.argmin(fitness),
fitness.shape)]

        population = update_states(population, fitness, neighborhood_size)

        print(f"Iteration {iteration + 1}: Best Fitness = {best_fitness}")
    print(f"Best Solution: {best_solution}, Best Fitness: {best_fitness}")
    return best_solution, best_fitness

if _name_ == "_main_":
    parallel_cellular_algorithm()
```

PROGRAM 7

GENE EXPRESSION ALGORITHM

Algorithm:



```
Optimization via Gene Expression Algorithm

import numpy as np

def optimization_function(solution):
    return solution[0]**2 + solution[1]**2

def initialize_parameters():
    population_size = 50
    num_genes = 2
    mutation_rate = 0.1
    crossover_rate = 0.8
    num_generations = 100
    return population_size, num_genes, mutation_rate,
crossover_rate, num_generations

def initialize_population(population_size, num_genes):
    return np.random.uniform(-10, 10, (population_
size, num_genes))

def evaluate_fitness(population):
    return np.array([optimization_function(ind)
for ind in population])

def select_parents(population, fitness):
    probabilities = 1 / (fitness + 1e-6)
    probabilities /= probabilities.sum()
    indices = np.random.choice(len(population), size=len
(population), p=probabilities)
    return population[indices]
```

```
def crossover(parents, crossover_rate):
    offspring = []
    for i in range(0, len(parents), 2):
        if i+1 < len(parents) and np.random.random() < crossover_rate:
            point = np.random.randint(1, parents.shape[1])
            offspring1 = np.concatenate((parents[i, :point], parents[i+1, point:]))
            offspring2 = np.concatenate((parents[i+1, :point], parents[i, point:]))
            offspring.extend([offspring1, offspring2])
        else:
            offspring.extend([parents[i], parents[i+1]])
    return np.array(offspring)

def mutate(offspring, mutation_rate):
    for individual in offspring:
        if np.random.random() < mutation_rate:
            gene = np.random.randint(individual.size)
            individual[gene] += np.random.normal()
    return offspring

def genetic_expression_algorithm():
    population_size, num_genes, mutation_rate, num_generations = initialize_parameters()
    population = initialize_population(population_size, num_genes)
    best_solution = None
    best_fitness = float('inf')
    for generation in range(num_generations):
```

```
fitness = calculate_fitness(population)
min_fitness_idx = np.argmin(fitness)
if fitness[min_fitness_idx] < best_fitness:
    best_fitness = fitness[min_fitness_idx]
    best_solution = population[min_fitness_idx]

    parents = select_parents(population, fitness)
    offspring = crossover(parents, crossover_rate)
    population = mutate(offspring, mutation_rate)
    population = gene_expression(population)
    print(f"Generation {generation+1}: Best
Fitness = {best_fitness}")

    print("Best Solution: {best_solution}, Best
Fitness: {best_fitness}")
    return best_solution, best_fitness.

~~#~~
If __name__ == "__main__":
    gene_expression_algorithm()
```

output:

Best Solution: [0.00434879 0.00143412],
Best Fitness: 2.09687113742897e-05.

Code:

```
import numpy as np

def optimization_function(solution):
    return solution[0]*2 + solution[1]*2

def initialize_parameters():
    population_size = 50
    num_genes = 2
    mutation_rate = 0.1
    crossover_rate = 0.8
    num_generations = 100
    return population_size, num_genes, mutation_rate, crossover_rate, num_generations

def initialize_population(population_size, num_genes):
    return np.random.uniform(-10, 10, (population_size, num_genes))

def evaluate_fitness(population):
    return np.array([optimization_function(ind) for ind in population])

def select_parents(population, fitness):
    probabilities = 1 / (fitness + 1e-6)
    probabilities /= probabilities.sum()
    indices = np.random.choice(len(population), size=len(population), p=probabilities)
    return population[indices]

def crossover(parents, crossover_rate):
    offspring = []
    for i in range(0, len(parents), 2):
        if i + 1 < len(parents) and np.random.rand() < crossover_rate:
            point = np.random.randint(1, parents.shape[1])
            offspring1 = np.concatenate((parents[i, :point], parents[i + 1, point:]))
            offspring2 = np.concatenate((parents[i + 1, :point], parents[i, point:]))
            offspring.extend([offspring1, offspring2])
        else:
            offspring.extend([parents[i], parents[i + 1] if i + 1 < len(parents) else
parents[i]])
    return np.array(offspring)

def mutate(offspring, mutation_rate):
```

```
    for individual in offspring:
        if np.random.rand() < mutation_rate:
            gene = np.random.randint(individual.size)
            individual[gene] += np.random.normal(0, 1)

def gene_expression(population):
    return population

def gene_expression_algorithm():
    population_size, num_genes, mutation_rate, crossover_rate, num_generations =
initialize_parameters()

    population = initialize_population(population_size, num_genes)

    best_solution = None
    best_fitness = float('inf')

    for generation in range(num_generations):
        fitness = evaluate_fitness(population)

        min_fitness_idx = np.argmin(fitness)
        if fitness[min_fitness_idx] < best_fitness:
            best_fitness = fitness[min_fitness_idx]
            best_solution = population[min_fitness_idx]

        parents = select_parents(population, fitness)
        offspring = crossover(parents, crossover_rate
        population = mutate(offspring, mutation_rate)
        population = gene_expression(population)
        print(f"Generation {generation + 1}: Best Fitness = {best_fitness}")
    print(f"Best Solution: {best_solution}, Best Fitness: {best_fitness}")
    return best_solution, best_fitness

if _name_ == "_main_":
    gene_expression_algorithm()
```