VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB RECORD

Bio Inspired Systems (23CS5BSBIS)

Submitted by

Suhan S (1BM23CS344)

in partial fulfillment for the award of the degree of

BACHELOR OF ENGINEERING
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 **Suhan S (1BM23CS344),** 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/suhan-s255/SUHAN_S_1BM23CS344_BIS_LAB.git

Program 1

Genetic Algorithm for Optimization Problems

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Genetic Algorithm

5 Main Phases - Initialization
Fitness Assignment
Selection
Crossover
Termination

Steps:

1) Selecting encoding techiques
   0 to 31

2) Select the initial population - 4

String No.	Initial Population	x Value	Fitness $f(x) = x^2$	Prob $\frac{f(x)}{\Sigma f(x)}$	% prob	Expected Count $\frac{f(x)}{Avg(\Sigma f(x))}$	Actual Count (floor value)
1	01100	12	144	0.1247	12.47	0.49	1
2	11001	25	625	0.5411	54.11	2.164	2
3	00101	5	25	0.0216	2.16	0.086	0
4	10011	19	361	0.3125	31.25	1.25	1
Sum			1155				
Avg			288.75				
Max			625				

3) Select Mating Pool

String No.	Mating Pool	Crossover Point	Offspring after Crossover	x value	fitness $f(x) = x^2$
1	01100	4	01101	13	169
2	11001		11000	24	576
3	11001	2	11011	27	729
4	10011		10001	17	289
Sum					
Avg					
Max					

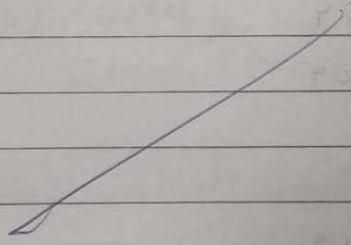
4) Crossover : Random 4 & 2

Max value - 729

~~5) Mutation~~

5) Mutation

String No.	offspring after crossover	Mutation Chromosome for flipping	offspring after Mutation	x Value	fitness $f(x) = x^2$
1	01101	10000	11101	29	841
2	11000	00000	11000	24	576
3	11011	00000	11011	27	729
4	10001	00101	10100	20	400
Sum					2546
Avg					630.5
Max					841



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Code: Pseudo Code :-

```
import random
def fitness(x):
    return x**2

POPULATION_SIZE = 4
CHROMOSOME_LEN = 5
MUTATION_RATE = 0.1
GENERATIONS = 10

def binary_to_decimal(binary):
    return int(binary, 2)

def decimal_to_binary(n):
    return format(n, f'{CHROMOSE_LEN}')

def initialize_population():
    return [decimal_to_binary()]

def evaluate_population(population):
    return [fitness(binary_to_decimal(individual)) for
            individual in population]

def select_parents(population, fitness):
    parents = []
    for i in range(2):
        i,j = random.sample(range(len(population)), 2)
        if fitness[i] > fitness[j]:
            parents.append(population[i])
        else
            parents.append(population[j])
    return parents.
```

```
def crossover(parent1, parent2):
    point = random.randint(1, CHROMOSOME_LEN-1)
    child1 = parent1[:point] + parent2[point:]
    child2 = parent2[:point] + parent1[point:]
    return child1, child2

def mutate(individual):
    mutated = ""
    for bit in individual:
        if random.random() < MUTATION_RATE:
            mutated += '1' if bit == '0' else '0'
        else:
            mutated += bit
    return mutated

genetic algorithm()

final_x = express_gene(best_solution)
print(best_solution, final_x)
```

Select Mating pool
Mutation after Mating
Iterate
Note down the best value

Output

Gen 1 : x = 993 f(x) = 986049
Gen 2 : x = 1004 f(x) = 1008016
Gen 3 : x = 1022 f(x) = 1044484
Gen 4 : x = 1023 f(x) = 1046529
⋮
Gen 50 : x = 1023 f(x) = 1046529

Code:

```
import random

# Parameters
POP_SIZE = 1000
GENES = 5        # 5 bits to represent 0-31
GENERATIONS = 50
CROSSOVER_RATE = 0.7
MUTATION_RATE = 0.1

# Fitness function: f(x) = x^2
def fitness(binary_str):
    x = int(binary_str, 2)
    return x * x

# Create initial population of random 5-bit binary strings
def create_population():
    population = []
    for _ in range(POP_SIZE):
        individual = ''.join(random.choice('01') for _ in range(GENES))
        population.append(individual)
    return population

# Selection: Tournament Selection of size 2
def tournament_selection(pop):
    i1, i2 = random.sample(pop, 2)
    return i1 if fitness(i1) > fitness(i2) else i2

# Crossover: Single-point crossover
def crossover(parent1, parent2):
    if random.random() < CROSSOVER_RATE:
        point = random.randint(1, GENES - 1)
        child1 = parent1[:point] + parent2[point:]
        child2 = parent2[:point] + parent1[point:]
        return child1, child2
    else:
        return parent1, parent2

# Mutation: Bit flip mutation
def mutate(individual):
    new_ind = ''
    for bit in individual:
        if random.random() < MUTATION_RATE:
            new_ind += '1' if bit == '0' else '0'
        else:
            new_ind += bit
    return new_ind

# Main GA function
```

```
def genetic_algorithm():
    population = create_population()
    best_individual = None
    best_fitness = -1

    for gen in range(1, GENERATIONS + 1):
        new_population = []

        # Evaluate and keep track of best
        for ind in population:
            ind_fit = fitness(ind)
            if ind_fit > best_fitness:
                best_fitness = ind_fit
                best_individual = ind

        # Print best in current generation
        print(f"Generation {gen}: Best Individual = {best_individual} (x={int(best_individual, 2)}),
Fitness = {best_fitness}")

        # Create new generation
        while len(new_population) < POP_SIZE:
            parent1 = tournament_selection(population)
            parent2 = tournament_selection(population)
            child1, child2 = crossover(parent1, parent2)
            child1 = mutate(child1)
            child2 = mutate(child2)
            new_population.extend([child1, child2])

        population = new_population[:POP_SIZE]

    print(f"\nBest solution found: {best_individual} (x={int(best_individual, 2)}), Fitness =
{best_fitness}")

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

Program 2

Particle Swarm Optimization for Function Optimization

Algorithm:

Iteration 1

Part No.	Position (x,y)	Velocity (v_x, v_y)	pbest (x,y)	gbest (x,y)	Fitness values
P1	(1,1)	(0,0)	(1,1)	(1,1)	2
P2	(-1,1)	(0,0)	(-1,1)	(1,1)	2
P3	(0.5, -0.5)	(0,0)	(0.5, 0.5)	(1,1)	0.5
P4	(-1,-1)	(0,0)	(-1,-1)	(1,1)	2
P5	(0.25, 0.25)	(0,0)	(0.25, 0.25)	(1,1)	0.125

Best Fitness Value = 0.125 (P5)

So, gbest = (0.25, 0.25)

Iteration 2

Part No	Pos (x,y)	Velocity (v_x, v_y)	pbest (x,y)	gbest (x,y)	Fitness values
P1	(1,1)	(-0.75, -0.75)	1,1	(0.25, 0.25)	2
P2	(-1,1)	(1.25, -0.25)	-1,1	(0.25, 0.25)	2
P3	(0.5, 0.5)	(-0.5, 1.25)	0.5, -0.5	(0.25, 0.25)	0.5
P4	(-1,-1)	(-0.75, 0.75)	-1,-1	(0.25, 0.25)	2
P5	(0.25, 0.25)	(0,0)	0.25, 0.25	(0.25, 0.25)	0.125

gbest remains (0.25, 0.25)

Iteration 3

Part No	Pos (x,y)	Velocity (Vx, Vy)	pbest (x,y)	gbest (x,y)	Fitness values
P1	1,1	-0.75, -0.75	1,1	0.25, 0.25	2
P2	-1,1	1.25, -0.25	-1,1	0.25, 0.25	2
P3	0.5, -0.5	-0.5, 1.25	0.5, -0.5	0.25, 0.25	0.5
P4	-1,-1	-0.75, 0.75	-1,-1	0.25, 0.25	2
P5	0.25, 0.25	0,0	0.25, 0.25	0.25, 0.25	0.125

Best Position: (0.25, 0.25)

Best Fitness: 0.125

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Particle Swarm Optimisation (PSO)

Pseudocode:

(1) p = particle.initialization()

(2) for i=1 to max:
    for each particle p in P do:
        $f_p = f(p)$

    if it is better than f pbest
        pbest = p
    end if
    end for
gbest = bestp in P
for each particle p in P do:

$$v_i^{t+1} = v_i^t + c_1 u_1^t (pb_i^t - p_i^t) + c_2 u_2^t (gb - p_i^t)$$

$$p_i^{t+1} = p_i^t + v_i^{t+1}$$

end for
end for

eg:- Iteration 1
F(x, y) = $x^2 + y^2$
Inertia weight (w) = 1
Cognitive constant (C_1) = 2
Social Constant (C_2) = 2
Initial solution set to (1000

Code:

```
import random

# Objective (fitness) function: De Jong function
def fitness_function(position):
    x, y = position
    return x*2 + y*2  # minimize this function

# PSO parameters
num_particles = 10
num_iterations = 50
W = 0.3       # inertia weight (from PDF)
C1 = 2        # cognitive coefficient
C2 = 2        # social coefficient

# Initialize particles and velocities
particles = [[random.uniform(-10, 10), random.uniform(-10, 10)] for _ in range(num_particles)]
velocities = [[0.0, 0.0] for _ in range(num_particles)]

# Initialize personal bests
pbest_positions = [p[:] for p in particles]
pbest_values = [fitness_function(p) for p in particles]

# Initialize global best
gbest_index = pbest_values.index(min(pbest_values))
gbest_position = pbest_positions[gbest_index][:]
gbest_value = pbest_values[gbest_index]

# PSO main loop
for iteration in range(num_iterations):
    for i in range(num_particles):
        r1, r2 = random.random(), random.random()

        # Update velocity
        velocities[i][0] = (W * velocities[i][0] +
                            C1 * r1 * (pbest_positions[i][0] - particles[i][0]) +
                            C2 * r2 * (gbest_position[0] - particles[i][0]))
        velocities[i][1] = (W * velocities[i][1] +
                            C1 * r1 * (pbest_positions[i][1] - particles[i][1]) +
                            C2 * r2 * (gbest_position[1] - particles[i][1]))

        # Update position
        particles[i][0] += velocities[i][0]
        particles[i][1] += velocities[i][1]

        # Evaluate fitness
        current_value = fitness_function(particles[i])

        # Update personal best
```

```
        if current_value < pbest_values[i]:
            pbest_positions[i] = particles[i][:]
            pbest_values[i] = current_value

            # Update global best
            if current_value < gbest_value:
                gbest_value = current_value
                gbest_position = particles[i][:]

    print(f"Iteration {iteration+1}/{num_iterations} | Best Value: {gbest_value:.6f} at
{gbest_position}")

print("\n☑ Optimal Solution Found:")
print(f"Best Position: {gbest_position}")
print(f"Minimum Value: {gbest_value}")
```

Program 3

Ant Colony Optimization for the Traveling Salesman Problem

Algorithm:

DATE: PAGE:

Complete tour by returning to starting city
Calculate total tour length
store tour and its length

Pheromone evaporation :
For all edges (i,j):
$T_{ij} = (1 - \text{evaporation\_rate}) * T_{ij}$

Pheromone update :
For each ant:
For each edge (i,j) in its tour:
$T_{ij} += Q / \text{tour\_length}$

Return the best-so-far tour as the optimal solution found

OUTPUT

It 1/100, best length : 22.3510
It 2/100, best length : 22.3510
It 3/100, best length : 22.3510
⋮

Best tour : [1, 0, 2, 4, 3, 1]
Best tour length : 22.3510

Input Matrix :

∞	2	4	5	7
2	∞	4	8	2
2	4	∞	1	3
5	8	1	∞	2
7	2	3	2	∞

∞

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Ant Colony Optimization for Traveling Salesman Problem

Initialize:
- pheromone[i][j] for all edges (i,j) to a small constant to
- parameters: alpha (α), beta (β), evaporation_rate, Q (pheromone deposit constant)
- cities = list of coordinates or nodes

Repeat for max_iterations:

For each ant:
- Randomly choose a starting city
- Initialize tour with starting city
- Mark starting city as visited

While not all cities visited:
For each unvisited city j:
- Compute η_{ij} = 1/distance between current city i and city j
- compute probability to move to city j:

Use wheel selection to choose next city based on P_{ij}
Move to selected city
Add city to tour
Mark city as visited

Code:

```
import random
import math

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

def initialize_pheromone(num_cities, tau0):
    return [[tau0 for _ in range(num_cities)] for _ in range(num_cities)]

def roulette_wheel_selection(probabilities):
    r = random.random()
    cumulative = 0.0
    for i, p in enumerate(probabilities):
        cumulative += p
        if r <= cumulative:
            return i
    return len(probabilities) - 1  # in case of rounding errors

def ant_colony_optimization(cities, alpha=1.0, beta=5.0, evaporation_rate=0.5, Q=100,
max_iterations=100, num_ants=10):
    num_cities = len(cities)
    pheromone = initialize_pheromone(num_cities, tau0=0.1)

    best_tour = None
    best_length = float('inf')

    for iteration in range(max_iterations):
        all_tours = []
        all_lengths = []

        for _ in range(num_ants):
            start_city = random.randint(0, num_cities - 1)
            visited = {start_city}
            tour = [start_city]
            current_city = start_city

            while len(visited) < num_cities:
                probabilities = []
                unvisited_cities = [city for city in range(num_cities) if city not in visited]

                denominator = 0
                for j in unvisited_cities:
                    dist = distance(cities[current_city], cities[j])
                    eta = 1.0 / dist if dist > 0 else 1e10  # avoid div by zero
                    denominator += (pheromone[current_city][j] ** alpha) * (eta ** beta)

                for j in unvisited_cities:
                    dist = distance(cities[current_city], cities[j])
```

```
                eta = 1.0 / dist if dist > 0 else 1e10
                numerator = (pheromone[current_city][j] ** alpha) * (eta ** beta)
                probabilities.append(numerator / denominator)

            next_city_index = roulette_wheel_selection(probabilities)
            next_city = unvisited_cities[next_city_index]
            tour.append(next_city)
            visited.add(next_city)
            current_city = next_city

        # Complete the tour by returning to start city
        tour.append(start_city)

        # Calculate total tour length
        length = 0
        for i in range(len(tour) - 1):
            length += distance(cities[tour[i]], cities[tour[i + 1]])

        all_tours.append(tour)
        all_lengths.append(length)

        if length < best_length:
            best_length = length
            best_tour = tour

    # Pheromone evaporation
    for i in range(num_cities):
        for j in range(num_cities):
            pheromone[i][j] *= (1 - evaporation_rate)

    # Pheromone update
    for tour, length in zip(all_tours, all_lengths):
        deposit = Q / length
        for i in range(len(tour) - 1):
            a, b = tour[i], tour[i + 1]
            pheromone[a][b] += deposit
            pheromone[b][a] += deposit  # if symmetric

    print(f"Iteration {iteration+1}/{max_iterations}, best length: {best_length:.4f}")

return best_tour, best_length

# Example usage:
if __name__ == "__main__":
    # Define some cities (x, y)
    cities = [(0, 0), (1, 5), (5, 2), (6, 6), (8, 3)]
    best_tour, best_length = ant_colony_optimization(cities)
    print("Best tour:", best_tour)
    print("Best tour length:", best_length
```

Program 4

Cuckoo Search (CS)

Algorithm:

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Cuckoo Search Algorithm

BEGIN
Initialize N nests (random item selections)
For each nest:
Repair if overweight; compute fitness (total val)

REPEAT until MaxGen():
FOR each cuckoo():
Generate new solution by levy flight.
Repair if overweight: compute fitness
If better than random nest → replace it

Abandon Pa Fraction of worst nests
generate new random nests & repeat if needed
Keep best nest as current best.
END REPEAT

OUTPUT best solution and its total value
END

Input
values = [60, 100, 120]
weights = [10, 20, 30]
Capacity = 50

Output
Best Solution: [0, 1, 1]
Total Value: 220
Total Weight: 50

Code:

```
# --- Cuckoo Search Algorithm for 0/1 Knapsack Problem ---
import numpy as np
import math  # ☑ FIX: use the standard math library for gamma, sin, pi

# Problem Definition
values = np.array([60, 100, 120, 90, 30])     # value of items
weights = np.array([10, 20, 30, 25, 5])       # weight of items
capacity = 50                                 # maximum weight allowed
num_items = len(values)

# Fitness Function
def fitness(solution):
    total_weight = np.sum(solution * weights)
    total_value = np.sum(solution * values)
    if total_weight > capacity:
        return 0  # invalid solution
    return total_value

# Levy Flight function
def levy_flight(Lambda):
    # Mantegna's algorithm for Levy distribution
    sigma = (math.gamma(1 + Lambda) * math.sin(math.pi * Lambda / 2) /
             (math.gamma((1 + Lambda) / 2) * Lambda * 2 ** ((Lambda - 1) / 2))) ** (1 / Lambda)
    u = np.random.randn() * sigma
    v = np.random.randn()
    step = u / (abs(v) ** (1 / Lambda))
    return step

# --- Cuckoo Search Parameters ---
num_nests = 10
max_iter = 100
Pa = 0.25  # Discovery rate (probability a host bird discovers cuckoo's egg)
Lambda = 1.5  # Levy flight parameter

# Initialize nests (each nest = potential solution)
nests = np.random.randint(0, 2, (num_nests, num_items))
fitness_values = np.array([fitness(n) for n in nests])

# --- Main Loop ---
for t in range(max_iter):
    # Generate new solutions via Levy flight
    for i in range(num_nests):
        new_nest = nests[i].copy()
        step_size = levy_flight(Lambda)

        # Randomly flip bits depending on step size
        for j in range(num_items):
            if np.random.rand() < abs(step_size) % 1:  # probabilistic mutation
```

```
                new_nest[j] = 1 - new_nest[j]  # flip 0/1

        # Evaluate new solution
        new_fitness = fitness(new_nest)
        if new_fitness > fitness_values[i]:
            nests[i] = new_nest
            fitness_values[i] = new_fitness

    # Abandon a fraction of the worst nests (discovery)
    num_abandon = int(Pa * num_nests)
    worst_indices = np.argsort(fitness_values)[:num_abandon]
    for idx in worst_indices:
        nests[idx] = np.random.randint(0, 2, num_items)
        fitness_values[idx] = fitness(nests[idx])

    # Track best nest
    best_idx = np.argmax(fitness_values)
    best_nest = nests[best_idx]
    best_fit = fitness_values[best_idx]

    if t % 10 == 0:
        print(f"Iteration {t}: Best fitness = {best_fit}")

# --- Output Final Result ---
print("\nBest Solution Found:")
print("Items selected:", best_nest)
print("Total Value:", np.sum(best_nest * values))
print("Total Weight:", np.sum(best_nest * weights))
```

Program 5

Grey Wolf Optimizer (GWO)

Algorithm:

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Grey Wolf Optimizer (GWO)

Pseudocode:

```
BEGIN
  Initialize number of wolves (N) and tasks
  Generate random schedules for all wolves
  Evaluate fitness (e.g., total time or cost)

  Identify α (best), β (second best), & δ (third best) wolves

  WHILE (not reached max iterations)
      FOR each wolf
          Update position using α, β, δ (follow the leaders)
          Repair schedule if invalid
          Recalculate fitness
      END FOR

      Update α, β, δ wolves
  END WHILE

  OUTPUT best schedule (α wolf)
END
```

Input

tasks = [3, 5, 2, 7, 4]

Output

Best Task Schedule: [2, 3, 4, 5, 7]

Total Completion Time: 21

Sen Roa 17/10

Code:

```
# --- Grey Wolf Optimizer for Task Scheduling ---
import numpy as np

# ----------------------------
# Problem Definition
# ----------------------------
num_tasks = 10
num_machines = 3

# Random task execution times (in arbitrary units)
task_times = np.random.randint(5, 20, num_tasks)

# Random machine speeds (higher = faster)
machine_speeds = np.random.uniform(0.8, 1.5, num_machines)

def calculate_makespan(schedule):
    """Calculate the total completion time for a schedule."""
    machine_loads = np.zeros(num_machines)
    for i, machine in enumerate(schedule):
        exec_time = task_times[i] / machine_speeds[machine]
        machine_loads[machine] += exec_time
    return np.max(machine_loads)  # Makespan = max machine load

# Fitness function: we minimize makespan, so return 1 / makespan
def fitness_function(schedule):
    return 1 / (1 + calculate_makespan(schedule))

# ----------------------------
# GWO Parameters
# ----------------------------
num_wolves = 15
max_iter = 100

# Each wolf = one possible task assignment [0..num_machines-1]
wolves = np.random.randint(0, num_machines, (num_wolves, num_tasks))
fitness = np.zeros(num_wolves)

# Initialize Alpha, Beta, Delta
alpha, beta, delta = np.zeros(num_tasks, dtype=int), np.zeros(num_tasks, dtype=int),
np.zeros(num_tasks, dtype=int)
alpha_score, beta_score, delta_score = -np.inf, -np.inf, -np.inf

# ----------------------------
# Main GWO Loop
# ----------------------------
for iteration in range(max_iter):
    for i in range(num_wolves):
        fitness[i] = fitness_function(wolves[i])
```

```
        # Update Alpha, Beta, Delta wolves
        if fitness[i] > alpha_score:
            delta_score, delta = beta_score, beta.copy()
            beta_score, beta = alpha_score, alpha.copy()
            alpha_score, alpha = fitness[i], wolves[i].copy()
        elif fitness[i] > beta_score:
            delta_score, delta = beta_score, beta.copy()
            beta_score, beta = fitness[i], wolves[i].copy()
        elif fitness[i] > delta_score:
            delta_score, delta = fitness[i], wolves[i].copy()

    a = 2 - iteration * (2 / max_iter)  # Decrease linearly from 2 to 0

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

            A1 = 2 * a * r1 - a
            C1 = 2 * r2
            D_alpha = abs(C1 * alpha[j] - wolves[i][j])
            X1 = alpha[j] - A1 * D_alpha

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

            r1, r2 = np.random.rand(), np.random.rand()
            A3 = 2 * a * r1 - a
            C3 = 2 * r2
            D_delta = abs(C3 * delta[j] - wolves[i][j])
            X3 = delta[j] - A3 * D_delta

            new_position = (X1 + X2 + X3) / 3

            # Discretize (assign to nearest machine)
            wolves[i][j] = int(np.clip(round(new_position), 0, num_machines - 1))

    if iteration % 10 == 0:
        print(f"Iteration {iteration}: Best makespan = {calculate_makespan(alpha):.3f}")

# ----------------------------
# Results
# ----------------------------
best_makespan = calculate_makespan(alpha)
print("\n☑ Best Schedule Found:")
for i, machine in enumerate(alpha):
```

```
    print(f"Task {i+1} → Machine {machine+1}")

print(f"\nTotal Makespan: {best_makespan:.3f}")
print(f"Machine Speeds: {np.round(machine_speeds, 2)}")
print(f"Task Times: {task_times}")
```

Program 6
Parallel Cellular Algorithms and Programs

Algorithm:

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```
        if f(xi) < f(best_cell)
            best_cell = xi
        end if
    end for
end for
print("Best solution:", best_cell)
print("Best fitness:", f(best_cell))
```

output :-

Best solution found : [2.23000242e-05 3.00922293e-05]
Best fitness value : 2.78311034662692 7e-07

Parallel cellular Algorithm

Pseudocode:

Initialization:
Let $f(x)$
Let grid size
Let neighbourhood
Let max_iter
Let bounds
Let α, β

for $i \leftarrow 1$ to num_cells:
    initialize x_i randomly within the search
    evaluate fitness $f(x_i)$
end for

best_cell = cell with the lowest fitness

for $t \leftarrow 1$ to max_iter:
    for each cell i in parallel:
        N_i = Let of neighbouring cells of cell i
        x_i best neighbours = neighbours in N_i with best fitness

        r = random number in $[0,1]$
        x_i-new = $x_i + r \times (x\text{-best neighbour} - x_i)$
        f-new = $f(x_i\text{-new})$
        if f-new $< f(x_i)$
            $x_i = x_i$-new
        end if

Code:

```
import numpy as np
from multiprocessing import Pool

# --- Step 1: Define the problem (Objective function) ---
def objective_function(x):
    # Example: minimize f(x) = x^2 - 4x + 4
    return x**2 - 4*x + 4

# --- Step 2: Initialize parameters ---
GRID_SIZE = (10, 10)   # 10x10 grid = 100 cells
ITERATIONS = 100
VALUE_RANGE = (-10, 10)
NEIGHBORHOOD_RADIUS = 1  # 3x3 neighborhood

# --- Step 3: Initialize population (random values for cells) ---
grid = np.random.uniform(VALUE_RANGE[0], VALUE_RANGE[1], GRID_SIZE)

# --- Step 4: Fitness evaluation function ---
def evaluate_fitness(grid):
    return objective_function(grid)

# --- Step 5: Get neighborhood indices with wrapping ---
def get_neighborhood_indices(i, j, grid_shape, radius):
    rows, cols = grid_shape
    neighbors = []
    for dx in range(-radius, radius + 1):
        for dy in range(-radius, radius + 1):
            if dx == 0 and dy == 0:
                continue
            ni, nj = (i + dx) % rows, (j + dy) % cols
            neighbors.append((ni, nj))
    return neighbors

# --- Step 6: Update rule for each cell ---
def update_cell(args):
    i, j, grid = args
    neighbors = get_neighborhood_indices(i, j, grid.shape, NEIGHBORHOOD_RADIUS)
    # Find best neighbor (lowest fitness)
    best_neighbor = min(neighbors, key=lambda n: objective_function(grid[n]))
    # Example rule: average current cell and best neighbor values
    new_value = (grid[i, j] + grid[best_neighbor]) / 2
    return i, j, new_value

# --- Step 7: Parallel iteration ---
def run_parallel_cellular_algorithm():
    global grid
    best_value = None
    best_fitness = float("inf")
```

```
    for iteration in range(ITERATIONS):
        # Evaluate fitness of all cells
        fitness_grid = evaluate_fitness(grid)

        # Track best cell
        current_best_idx = np.unravel_index(np.argmin(fitness_grid), grid.shape)
        current_best_value = grid[current_best_idx]
        current_best_fitness = fitness_grid[current_best_idx]

        if current_best_fitness < best_fitness:
            best_value = current_best_value
            best_fitness = current_best_fitness

        # Parallel update of grid
        with Pool() as pool:
            updates = pool.map(update_cell, [(i, j, grid) for i in range(grid.shape[0]) for j in
range(grid.shape[1])])

        # Apply updates
        new_grid = np.copy(grid)
        for i, j, val in updates:
            new_grid[i, j] = val
        grid = new_grid

        # Print progress
        print(f"Iteration {iteration+1}: Best Fitness = {best_fitness:.6f}, Best Value = {best_value:.6f}")

    print("\n=== Final Result ===")
    print(f"Best Value Found: {best_value}")
    print(f"Best Fitness: {best_fitness:.6f}")

# --- Run the algorithm ---
if __name__ == "__main__":
    run_parallel_cellular_algorithm()
```

Program 7

Optimization via Gene Expression Algorithms

Algorithm:

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GENE EXPRESSION ALGORITHM

Step1: Fitness function: $f(x) = x^2$

Encoding technique : 0 to 31

use chromosome of fixed length (genotype)

Step2: Initial Population

S.no.	(Genotype) Initial chrosome	Phenotype (expression)	value	fitness	P
1	+xx	x^2	12	144	0.1247
2	+xx	2x	25	625	0.5411
3	x	x	5	25	0.0216
4	-x2	x-2	19	361	0.3125
Sum				1155	
avg				288.75	
max				625	

actual count	expected count
1	0.5
2	2.1
0	0.08
1	1.25

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Step 3: Selection of mating pool

S.no.	Selected chromosome	Crossover point	Offspring	Phenotype
1	+xx	2	xx	x*(x+...)
2	+xx	1	+xx	2x
3	+xx	3	+x-	x+(x-...)
4	+x2	1	+x2	x+2

x value	fitness
13	169
24	576
27	729
17	289

Step 4: crossover: perform crossover randomly chosen gene position (not raw bits)

max fitness after crossover = 729

Step 5 mutation

S.no.	Offspring before mutation	mutation applied	Offspring after mutation	Phenotype
1	*x+	+ → -	*x-	x*(x-...)
2	+xx	None	+xx	2x
3	+x-	- → +	-x+	x+x*x
4	+x2	None	+x2	x+2

x value	fitness
29	841
24	576
27	729
20	400

Step6: Gene expression and evaluation

Decode each genotype → phenotype
calculate fitness

$\Sigma f(x) = 841 + 576 + 729 + 400 = 2546$

avg = 636.5
max = 841

Step7: Iterate until convergence

Repeat step 3 to 6 until fitness improvement is negligible or generator limit has reached.

Code: Pseudocode:-

```
POP_SIZE = 100
GENES = 5
GENERATIONS = 50
CROSSOVER_RATE = 0.7
MUTATION_RATE = 0.1

def fitness(x):
    return xxx

def create_population():
    population = []
    for i in range(POP_SIZE):
        population.append(genes)
    return population

def express_gene(gene_sequence): return
    return [fitness(express_gene(ind)) ]
def tournament_selection(population, fitness_value):
    i1, i2 = random.sample(range(len(population)), 2)
    return population

def crossover(p1, p2):
    if random.random() < CROSSOVER_RATE:
        point = random.randint(1, GENES-1)
        return child1, child2
    else
        return p1, p2
```

```
def mutate(individual):
    mutated = ''
    for bit in individual:
        if random.random() < MUTATION_RATE:
            mutated += '1'
        else:
            mutate += bit
    return mutated

def gen_expression_algorithm()

final_x = express_gene(best_solution)
print(best_solution, final_x)
```

OUTPUT:-

G1 : Best = 11111 (x = 31), Fitness = 961
G2 : Best = 11111 (x = 31), Fitness = 961
G3 : Best = 11111 (x = 31), Fitness = 961
:
G50 : Best = 11111 (x = 31), Fitness = 961

Best solution found : 11111 (x = 31), Fitness = 961

Code:

```
import random

# Step 2: Initialize Parameters
POP_SIZE = 1000            # Number of individuals in the population
GENES = 5              # Number of genes per chromosome (5 bits = 0 to 31)
GENERATIONS = 50        # Number of generations to run
CROSSOVER_RATE = 0.7     # Probability of crossover
MUTATION_RATE = 0.1      # Probability of mutation per gene

# Step 1: Define the Problem
# Optimization function: f(x) = x^2 (maximize)
def fitness(x):
    return x * x

# Step 3: Initialize Population (each gene is a bit string of length GENES)
def create_population():
    population = []
    for _ in range(POP_SIZE):
        genes = ''.join(random.choice('01') for _ in range(GENES))
        population.append(genes)
    return population

# Step 8: Gene Expression - Decode binary gene to integer x
def express_gene(gene_sequence):
    return int(gene_sequence, 2)

# Step 4: Evaluate Fitness
def evaluate_population(population):
    return [fitness(express_gene(ind)) for ind in population]

# Step 5: Selection - Tournament Selection
def tournament_selection(population, fitness_values):
    i1, i2 = random.sample(range(len(population)), 2)
    return population[i1] if fitness_values[i1] > fitness_values[i2] else population[i2]

# Step 6: Crossover - Single-point crossover
def crossover(parent1, parent2):
    if random.random() < CROSSOVER_RATE:
        point = random.randint(1, GENES - 1)
        child1 = parent1[:point] + parent2[point:]
        child2 = parent2[:point] + parent1[point:]
        return child1, child2
    else:
        return parent1, parent2

# Step 7: Mutation - Bit flip mutation
def mutate(individual):
    mutated = ''
```

```
    for bit in individual:
        if random.random() < MUTATION_RATE:
            mutated += '1' if bit == '0' else '0'
        else:
            mutated += bit
    return mutated

# Step 9: Main Loop
def gene_expression_algorithm():
    population = create_population()
    best_solution = None
    best_fitness = -1

    for gen in range(1, GENERATIONS + 1):
        fitness_values = evaluate_population(population)

        # Track best individual
        for i in range(len(population)):
            if fitness_values[i] > best_fitness:
                best_fitness = fitness_values[i]
                best_solution = population[i]

        # Print best of this generation
        x_val = express_gene(best_solution)
        print(f"Generation {gen}: Best = {best_solution} (x = {x_val}), Fitness = {best_fitness}")

        # Generate new population
        new_population = []
        while len(new_population) < POP_SIZE:
            parent1 = tournament_selection(population, fitness_values)
            parent2 = tournament_selection(population, fitness_values)
            child1, child2 = crossover(parent1, parent2)
            child1 = mutate(child1)
            child2 = mutate(child2)
            new_population.extend([child1, child2])

        population = new_population[:POP_SIZE]

    # Step 10: Output Best Solution
    final_x = express_gene(best_solution)
    print(f"\nBest solution found: {best_solution} (x = {final_x}), Fitness = {best_fitness}")

# Entry Point
if __name__ == "__main__":
    gene_expression_algorithm()
```