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PROGRAM 1

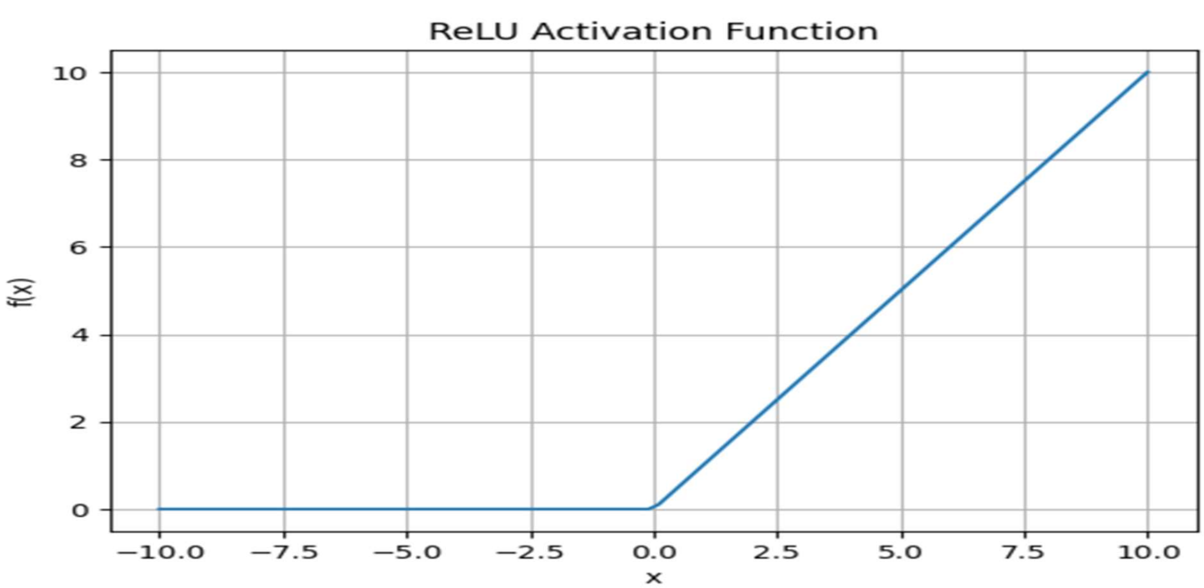
AIM: Program to implement basic activation functions.

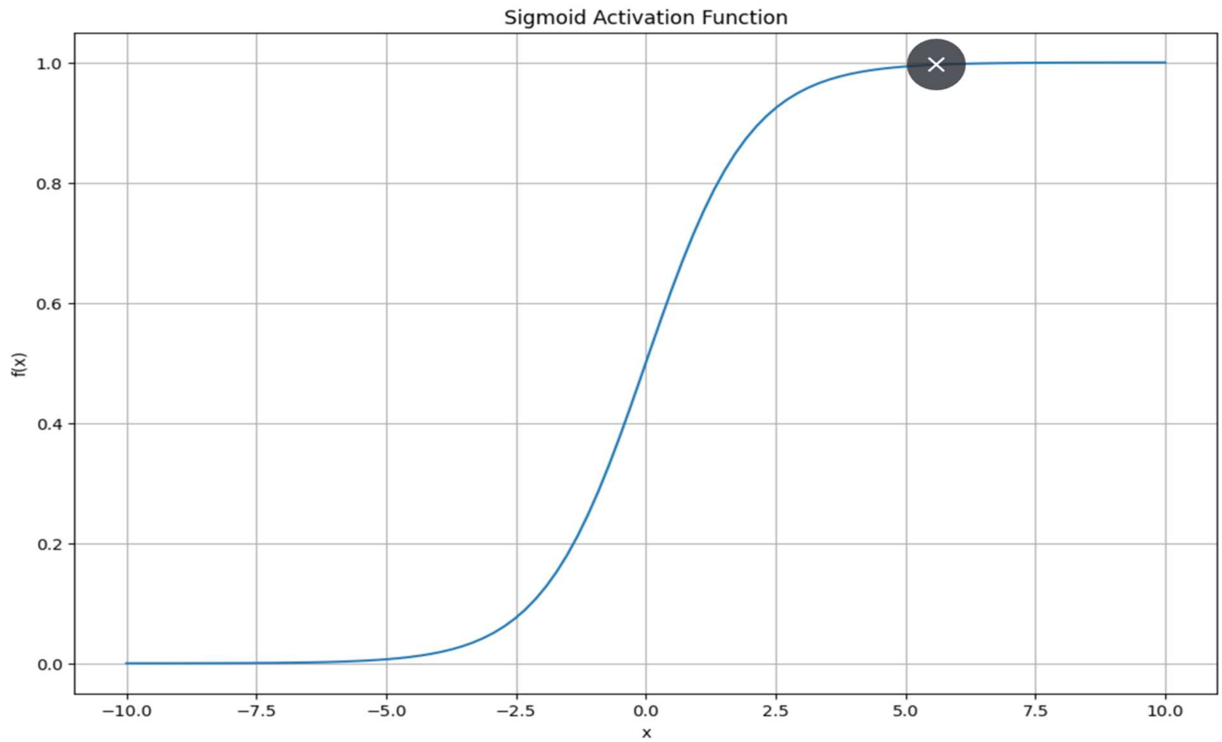
CODE:

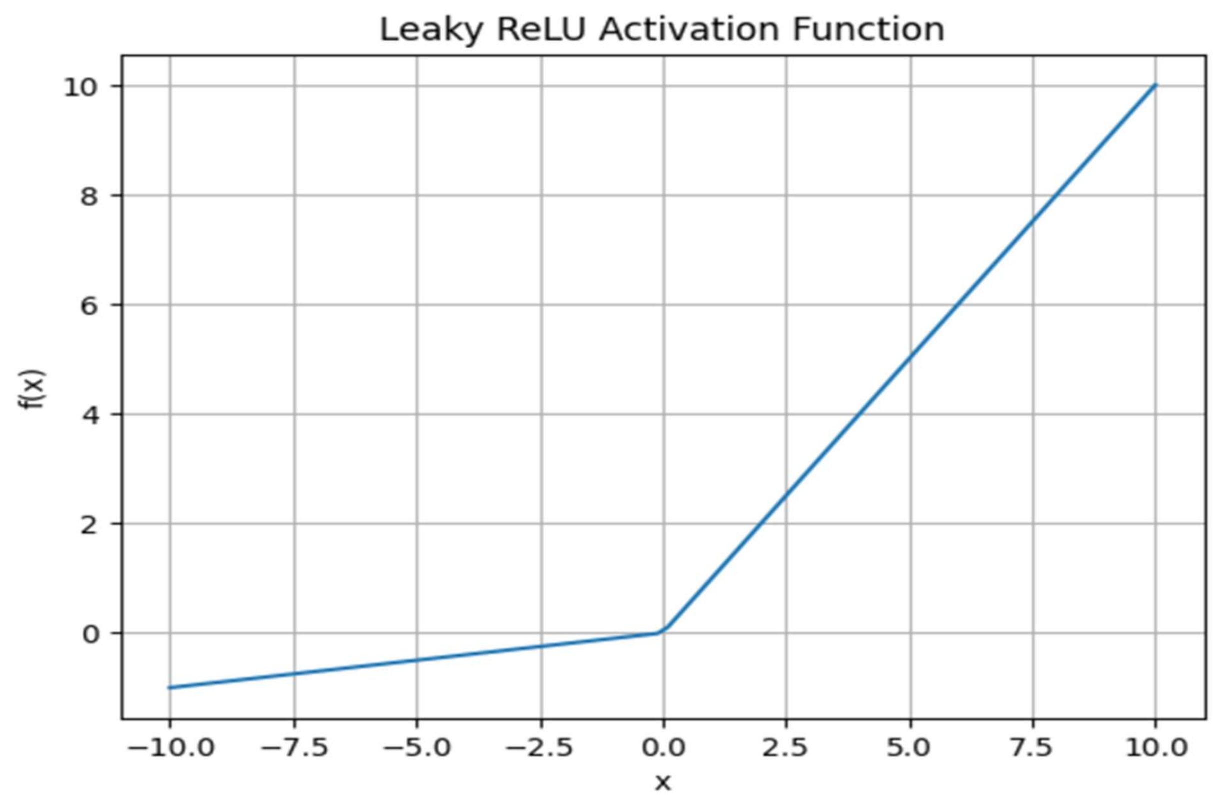
```
import numpy as np
import matplotlib.pyplot as plt
# Activation functions
def sigmoid(x):
    return 1 / (1 + np.exp(-x))
def tanh(x):
    return np.tanh(x)
def relu(x):
    return np.maximum(0, x)
def leaky_relu(x, alpha=0.01):
    return np.where(x > 0, x, alpha * x)
def softmax(x):
    exp_x = np.exp(x - np.max(x))  # Subtract max for numerical stability
    return exp_x / np.sum(exp_x)
# Plotting functions
def plot_activation(func, x, title, **kwargs):
    y = func(x, **kwargs) if kwargs else func(x)
    plt.plot(x, y, label=f'{func.__name__}')
    plt.title(title)
    plt.xlabel('x')
    plt.ylabel('f(x)')
    plt.grid()
    plt.show()
```

```
# Main program
if __name__ == "__main__":
    # Generate input values
    x = np.linspace(-10, 10, 100)

    # Plot activation functions
    plt.figure(figsize=(12, 8))
    plot_activation(sigmoid, x, "Sigmoid Activation Function")
    plot_activation(tanh, x, "Tanh Activation Function")
    plot_activation(relu, x, "ReLU Activation Function")
    plot_activation(leaky_relu, x, "Leaky ReLU Activation Function", alpha=0.1)
    # Softmax example (works on vectors)
    input_vector = np.array([1.0, 2.0, 3.0])
    softmax_result = softmax(input_vector)
    print(f"Softmax Output for {input_vector}: {softmax_result}")
```

OUTPUT:








```
Softmax Output for [1. 2. 3.]: [0.09003057 0.24472847 0.66524096]
```

PROGRAM 2

AIM: Program to implement McCulloch-Pitts Neuron.

CODE:

```
# Function to simulate McCulloch-Pitts neuron
def mcculloch_pitts_neuron(inputs, weights, threshold):
    # Compute the weighted sum of inputs
    weighted_sum = sum(i * w for i, w in zip(inputs, weights))
    # Generate output based on the threshold
    output = 1 if weighted_sum >= threshold else 0
    return output
# Main function
if __name__ == "__main__":
    # Define inputs, weights, and threshold
    inputs = [1, 0, 1]        # Binary inputs (example)
    weights = [2, 1, 2]       # Weights for each input
    threshold = 3             # Threshold value
    # Compute output
    output = mcculloch_pitts_neuron(inputs, weights, threshold)
    # Display results
    print(f"Inputs: {inputs}")
    print(f"Weights: {weights}")
    print(f"Threshold: {threshold}")
    print(f"Output: {output}")
```

OUTPUT:

```
Inputs: [1, 0, 1]
Weights: [2, 1, 2]
Threshold: 3
Output: 1
```

PROGRAM 3

AIM: Program to implement a simple Neuron with various activation functions

CODE:

```
import numpy as np
# Activation functions
def sigmoid(x):
    return 1 / (1 + np.exp(-x)
def tanh(x):
    return np.tanh(x)
def relu(x):
    return np.maximum(0, x)
def leaky_relu(x, alpha=0.01):
    return np.where(x > 0, x, alpha * x)
# Neuron implementation
def simple_neuron(inputs, weights, bias, activation_function):
    # Compute weighted sum + bias
    weighted_sum = np.dot(inputs, weights) + bias
    # Apply activation function
    output = activation_function(weighted_sum)
    return output
# Main program
if __name__ == "__main__":
    # Define inputs, weights, and bias
    inputs = [1.0, 2.0, 3.0]  # Example inputs
    weights = [0.2, 0.8, -0.5]  # Example weights
    bias = 2.0  # Example bias
```

```
# Compute outputs with different activation functions
print("Inputs:", inputs)
print("Weights:", weights)
print("Bias:", bias)
# Using Sigmoid Activation
sigmoid_output = simple_neuron(inputs, weights, bias, sigmoid)
print("Sigmoid Output:", sigmoid_output)
# Using Tanh Activation
tanh_output = simple_neuron(inputs, weights, bias, tanh)
print("Tanh Output:", tanh_output)
# Using ReLU Activation
relu_output = simple_neuron(inputs, weights, bias, relu)
print("ReLU Output:", relu_output)
# Using Leaky ReLU Activation
leaky_relu_output = simple_neuron(inputs, weights, bias, leaky_relu)
print("Leaky ReLU Output:", leaky_relu_output)
```

OUTPUT:

```
Inputs: [1.0, 2.0, 3.0]
Weights: [0.2, 0.8, -0.5]
Bias: 2.0
Sigmoid Output: 0.9088770389851438
Tanh Output: 0.9800963962661914
ReLU Output: 2.3
Leaky ReLU Output: 2.3
```

PROGRAM 4

AIM: Program to implement a simple perceptron using the perceptron learning algorithm

CODE:

```
import numpy as np
class Perceptron:
    def __init__(self, learning_rate=0.1, epochs=100):
        self.learning_rate = learning_rate
        self.epochs = epochs
        self.weights = None
        self.bias = None
    def activation_function(self, weighted_sum):
        return 1 if weighted_sum >= 0 else 0
    def fit(self, X, y):
        # Initialize weights and bias
        n_features = X.shape[1]
        self.weights = np.zeros(n_features)
        self.bias = 0
        for epoch in range(self.epochs):
            for idx, x_i in enumerate(X):
                # Calculate the weighted sum
                weighted_sum = np.dot(x_i, self.weights) + self.bias
                # Predict the output
                y_pred = self.activation_function(weighted_sum)
                # Update weights and bias if there is an error
                error = y[idx] - y_pred
                self.weights += self.learning_rate * error * x_i
```

```
            self.bias += self.learning_rate * error
    def predict(self, X):
        y_pred = [self.activation_function(np.dot(x_i, self.weights) + self.bias) for x_i in X]
        return np.array(y_pred)
# Main program
if __name__ == "__main__":
    # Define the input dataset (AND gate example)
    X = np.array([[0, 0],
                  [0, 1],
                  [1, 0],
                  [1, 1]])  # Input features
    y = np.array([0, 0, 0, 1])  # Target outputs (AND gate)
    # Create a perceptron model
    perceptron = Perceptron(learning_rate=0.1, epochs=10)
    # Train the perceptron
    perceptron.fit(X, y)
    # Test the perceptron
    predictions = perceptron.predict(X)
    print("Predicted outputs:", predictions)
    # Display learned weights and bias
    print("Learned weights:", perceptron.weights)
    print("Learned bias:", perceptron.bias)
```

OUTPUT:

```
Predicted outputs: [0 0 0 1]
Learned weights: [0.2 0.1]
Learned bias: -0.20000000000000004
```

PROGRAM 5

AIM: Program to implement delta and back propagation algorithm.

CODE:

```
import numpy as np

class NeuralNetwork:

    def __init__(self, input_size, hidden_size, output_size):

        # Initialize weights and biases with random values

        self.weights_input_hidden = np.random.randn(input_size, hidden_size)

        self.bias_hidden = np.zeros((1, hidden_size))

        self.weights_hidden_output = np.random.randn(hidden_size, output_size)

        self.bias_output = np.zeros((1, output_size))

        # Hyperparameters

        self.learning_rate = 0.1

    def sigmoid(self, x):

        return 1 / (1 + np.exp(-x))

    def sigmoid_derivative(self, x):

        return x * (1 - x)

    def forward_propagation(self, X):

        # Hidden layer

        self.hidden_sum = np.dot(X, self.weights_input_hidden) + self.bias_hidden

        self.hidden_activation = self.sigmoid(self.hidden_sum)

        # Output layer

        self.output_sum = np.dot(self.hidden_activation, self.weights_hidden_output) +
self.bias_output

        self.output_activation = self.sigmoid(self.output_sum)

        return self.hidden_activation, self.output_activation
```

```
def backpropagation(self, X, y):
        # Forward propagation
        _, predicted = self.forward_propagation(X)
        # Calculate output layer error
        output_error = y - predicted
        output_delta = output_error * self.sigmoid_derivative(predicted)
        # Calculate hidden layer error
        hidden_error = np.dot(output_delta, self.weights_hidden_output.T)
        hidden_delta = hidden_error * self.sigmoid_derivative(self.hidden_activation)
        # Update weights and biases
        # Output layer weights
        self.weights_hidden_output += self.learning_rate * np.dot(self.hidden_activation.T,
output_delta)
        self.bias_output += self.learning_rate * np.sum(output_delta, axis=0, keepdims=True)
        # Hidden layer weights
        self.weights_input_hidden += self.learning_rate * np.dot(X.T, hidden_delta)
        self.bias_hidden += self.learning_rate * np.sum(hidden_delta, axis=0, keepdims=True)
    def train(self, X, y, epochs):
        for _ in range(epochs):
            self.backpropagation(X, y)
    def predict(self, X):
        _, predicted = self.forward_propagation(X)
        return predicted
# Example usage
def main():
    # XOR problem example
    X = np.array([[0, 0], [0, 1], [1, 0], [1, 1]])
    y = np.array([[0], [1], [1], [0]])
```

```
    # Create and train neural network
    nn = NeuralNetwork(input_size=2, hidden_size=4, output_size=1)
    nn.train(X, y, epochs=10000)
    # Make predictions
    predictions = nn.predict(X)
    print("Predictions:")
    print(predictions)
    print("\nTarget:")
    print(y)
if __name__ == "__main__":
    main()
```

OUTPUT:

```
Predictions:
[[0.02905082]
 [0.95278358]
 [0.95520555]
 [0.05588007]]

Target:
[[0]
 [1]
 [1]
 [0]]
```

PROGRAM 6

AIM: Program to implement a simple perceptron with radial basis function (RBF) activation function

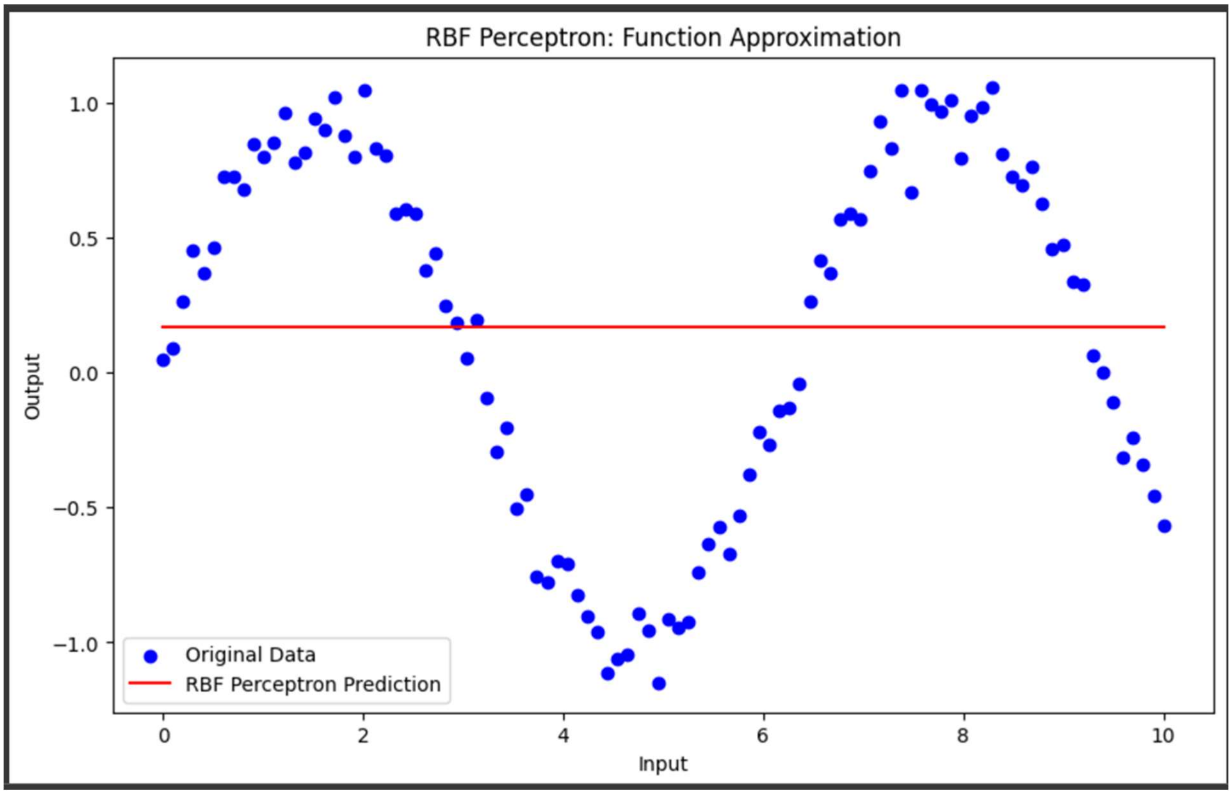
CODE:

```
import numpy as np

import matplotlib.pyplot as plt

class RBFPerceptron:

    def __init__(self, input_size, num_centers):

        # Randomly initialize centers

        self.centers = np.random.randn(num_centers, input_size)

        # Initialize spreads (width of RBF)

        # Spread determines the influence of each center

        self.spreads = np.ones(num_centers)

        # Initialize output layer weights

        self.weights = np.random.randn(num_centers)

    def rbf_activation(self, x):

        # Calculate squared Euclidean distances from centers

        distances = np.sum((self.centers - x)**2, axis=1)

        # Apply RBF (Gaussian) activation

        # exp(-||x - center||^2 / (2 * spread^2))

        activations = np.exp(-distances / (2 * self.spreads**2))

        return activations

    def train(self, X, y, learning_rate=0.01, epochs=100):

        for _ in range(epochs):

            # Compute RBF activations for training samples

            rbf_outputs = np.array([self.rbf_activation(sample) for sample in X])

            # Update weights using least squares
```

```
        self.weights = np.linalg.lstsq(rbf_outputs, y, rcond=None)[0]
        # Optional: Adjust centers and spreads
        self._optimize_centers_and_spreads(X, y)
def _optimize_centers_and_spreads(self, X, y, learning_rate=0.01):
    # Compute current predictions
    current_predictions = self.predict(X)
    # Simple gradient-based center optimization
    for i in range(len(self.centers)):
        # Compute gradient for center position
        center_gradient = np.mean(
            2 * (current_predictions - y) *
            self.weights[i] *
            (X - self.centers[i]) /
            (self.spreads[i]**2)
        )
        # Update center position
        self.centers[i] -= learning_rate * center_gradient
    # Simple gradient-based spread optimization
    for i in range(len(self.spreads)):
        # Compute gradient for spread
        spread_gradient = np.mean(
            2 * (current_predictions - y) *
            self.weights[i] *
            np.sum((X - self.centers[i])**2) /
            (self.spreads[i]**3)
        )
        # Update spread (ensure positive)
        self.spreads[i] = max(0.1, self.spreads[i] - learning_rate * spread_gradient)
```

```
    def predict(self, X):
        # Compute RBF activations for input samples
        rbf_outputs = np.array([self.rbf_activation(sample) for sample in X])
        # Compute weighted sum of RBF activations
        predictions = np.dot(rbf_outputs, self.weights)
        return predictions
def main():
    # Generate synthetic regression data
    np.random.seed(42)
    X = np.linspace(0, 10, 100).reshape(-1, 1)
    y = np.sin(X).ravel() + np.random.normal(0, 0.1, X.shape[0])
    # Create and train RBF Perceptron
    rbf_perceptron = RBFPerceptron(input_size=1, num_centers=10)
    rbf_perceptron.train(X, y, epochs=200)
    # Make predictions
    y_pred = rbf_perceptron.predict(X)
    # Visualize results
    plt.figure(figsize=(10, 6))
    plt.scatter(X, y, color='blue', label='Original Data')
    plt.plot(X, y_pred, color='red', label='RBF Perceptron Prediction')
    plt.title('RBF Perceptron: Function Approximation')
    plt.xlabel('Input')
    plt.ylabel('Output')
    plt.legend()
    plt.show()
if __name__ == "__main__":
    main()
```

OUTPUT:



RBF Perceptron: Function Approximation
1.0
0.5
0.0
−0.5
−1.0
Output
0
2
4
6
8
10
Input
Original Data
RBF Perceptron Prediction

PROGRAM 7

AIM: Program to implement all the fuzzy set operations like max, min, complement, union, intersection.

CODE:

```
import numpy as np
class FuzzySetOperations:
    @staticmethod
    def complement(fuzzy_set):
        return [1 - x for x in fuzzy_set]
    @staticmethod
    def union(fuzzy_set1, fuzzy_set2):
        return [max(x, y) for x, y in zip(fuzzy_set1, fuzzy_set2)]
    @staticmethod
    def intersection(fuzzy_set1, fuzzy_set2):
        return [min(x, y) for x, y in zip(fuzzy_set1, fuzzy_set2)]
    @staticmethod
    def max_operation(fuzzy_set1, fuzzy_set2):
        return [max(x, y) for x, y in zip(fuzzy_set1, fuzzy_set2)]
    @staticmethod
    def min_operation(fuzzy_set1, fuzzy_set2):
        return [min(x, y) for x, y in zip(fuzzy_set1, fuzzy_set2)]
# Main program
if __name__ == "__main__":
    # Example fuzzy sets
    fuzzy_set1 = [0.1, 0.4, 0.7, 1.0]
    fuzzy_set2 = [0.2, 0.6, 0.5, 0.8]
    print("Fuzzy Set 1:", fuzzy_set1)
```

```
print("Fuzzy Set 2:", fuzzy_set2)
# Complement
complement1 = FuzzySetOperations.complement(fuzzy_set1)
print("\nComplement of Fuzzy Set 1:", complement1)
# Union
union_result = FuzzySetOperations.union(fuzzy_set1, fuzzy_set2)
print("Union of Fuzzy Set 1 and Fuzzy Set 2:", union_result)
# Intersection
intersection_result = FuzzySetOperations.intersection(fuzzy_set1, fuzzy_set2)
print("Intersection of Fuzzy Set 1 and Fuzzy Set 2:", intersection_result)
# Max operation
max_result = FuzzySetOperations.max_operation(fuzzy_set1, fuzzy_set2)
print("Max operation between Fuzzy Set 1 and Fuzzy Set 2:", max_result)
# Min operation
min_result = FuzzySetOperations.min_operation(fuzzy_set1, fuzzy_set2)
print("Min operation between Fuzzy Set 1 and Fuzzy Set 2:", min_result)
```

OUTPUT:

```
Fuzzy Set 1: [0.1, 0.4, 0.7, 1.0]
Fuzzy Set 2: [0.2, 0.6, 0.5, 0.8]

Complement of Fuzzy Set 1: [0.9, 0.6, 0.30000000000000004, 0.0]
Union of Fuzzy Set 1 and Fuzzy Set 2: [0.2, 0.6, 0.7, 1.0]
Intersection of Fuzzy Set 1 and Fuzzy Set 2: [0.1, 0.4, 0.5, 0.8]
Max operation between Fuzzy Set 1 and Fuzzy Set 2: [0.2, 0.6, 0.7, 1.0]
Min operation between Fuzzy Set 1 and Fuzzy Set 2: [0.1, 0.4, 0.5, 0.8]
```

PROGRAM 8

AIM: Program to design fuzzy control system form restaurant tipping problem.

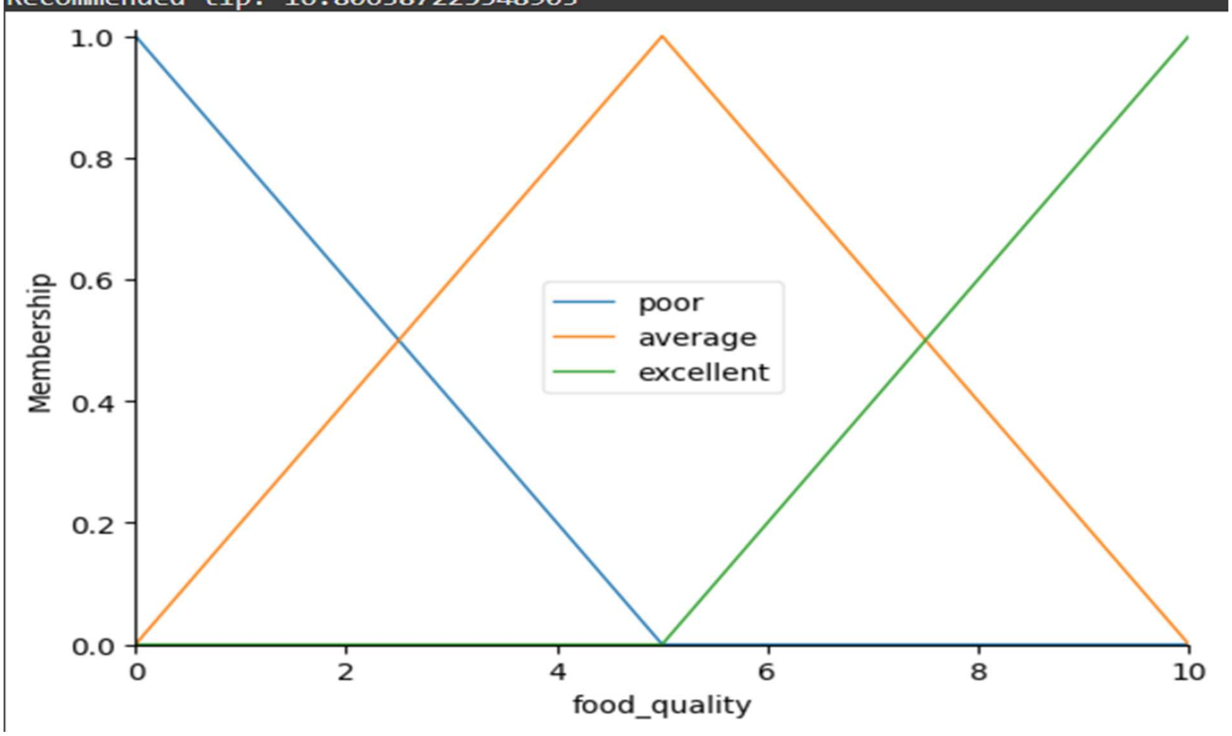
CODE:

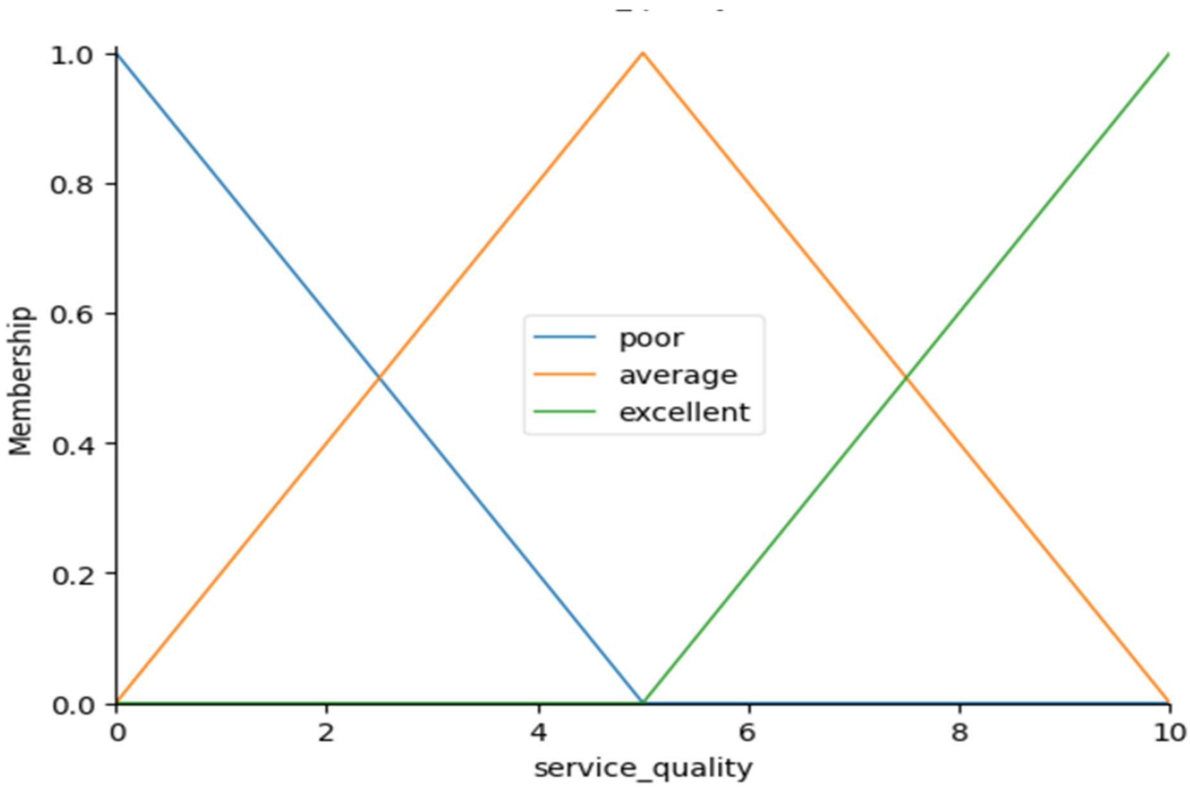
```
#Code 2
import numpy as np
import skfuzzy as fuzz
from skfuzzy import control as ctrl
# Step 1: Define fuzzy variables
food_quality = ctrl.Antecedent(np.arange(0, 11, 1), 'food_quality')
service_quality = ctrl.Antecedent(np.arange(0, 11, 1), 'service_quality')
tip = ctrl.Consequent(np.arange(0, 26, 1), 'tip')
# Step 2: Define fuzzy membership functions
food_quality['poor'] = fuzz.trimf(food_quality.universe, [0, 0, 5])
food_quality['average'] = fuzz.trimf(food_quality.universe, [0, 5, 10])
food_quality['excellent'] = fuzz.trimf(food_quality.universe, [5, 10, 10])
service_quality['poor'] = fuzz.trimf(service_quality.universe, [0, 0, 5])
service_quality['average'] = fuzz.trimf(service_quality.universe, [0, 5, 10])
service_quality['excellent'] = fuzz.trimf(service_quality.universe, [5, 10, 10])
tip['low'] = fuzz.trimf(tip.universe, [0, 0, 13])
tip['medium'] = fuzz.trimf(tip.universe, [0, 13, 25])
tip['high'] = fuzz.trimf(tip.universe, [13, 25, 25])
# Step 3: Define fuzzy rules
rule1 = ctrl.Rule(food_quality['poor'] | service_quality['poor'], tip['low'])
rule2 = ctrl.Rule(service_quality['average'], tip['medium'])
rule3 = ctrl.Rule(food_quality['excellent'] | service_quality['excellent'], tip['high'])
# Step 4: Create the control system
tipping_ctrl = ctrl.ControlSystem([rule1, rule2, rule3])
```

```
tipping = ctrl.ControlSystemSimulation(tipping_ctrl)
# Step 5: Provide inputs
tipping.input['food_quality'] = 6.5  # Input: Food quality score
tipping.input['service_quality'] = 9.0  # Input: Service quality score
# Step 6: Perform fuzzy inference
tipping.compute()
# Output the result
print("Recommended tip:", tipping.output['tip'])
# Optional: Visualize the results
food_quality.view()
service_quality.view()
tip.view(sim=tipping)
```

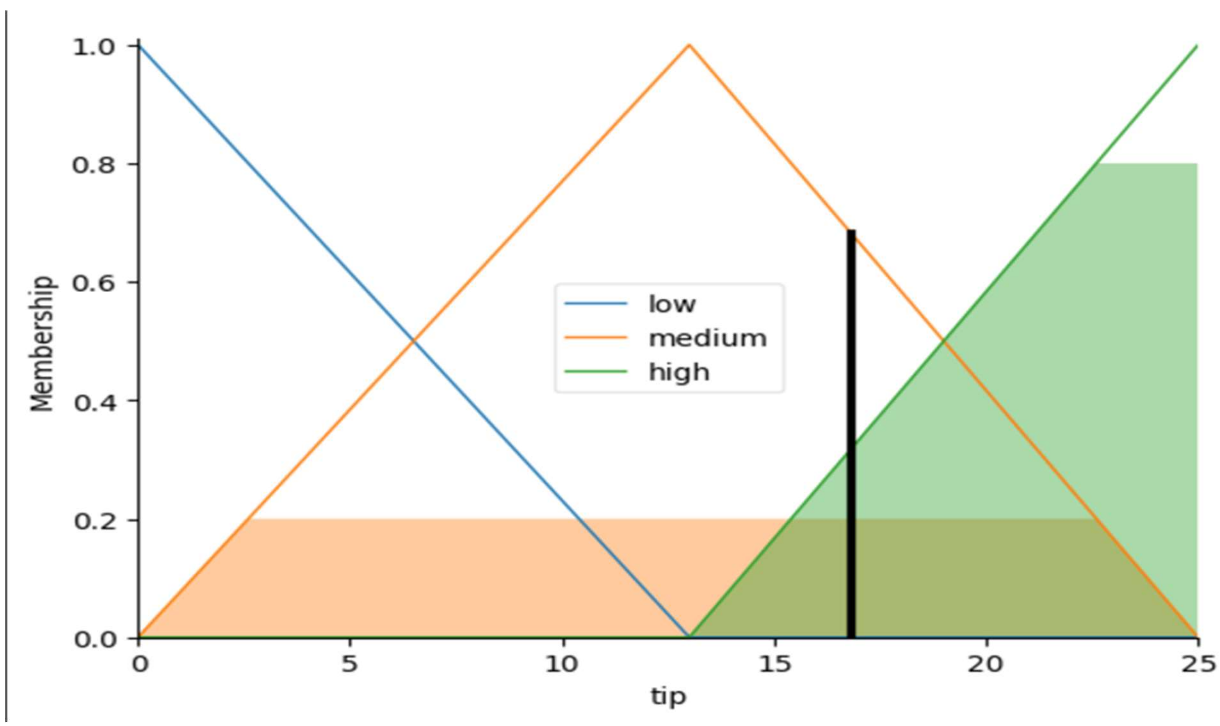
OUTPUT:

```
Recommended tip: 16.806387225548903
```





1.0
0.8
0.6
0.4
0.2
0.0
Membership
0
2
4
6
8
10
service_quality
poor
average
excellent



1.0
0.8
0.6
0.4
0.2
0.0
Membership
0
5
10
15
20
25
tip
low
medium
high

PROGRAM 9

AIM: Program to design fuzzy control system form AC temperature.

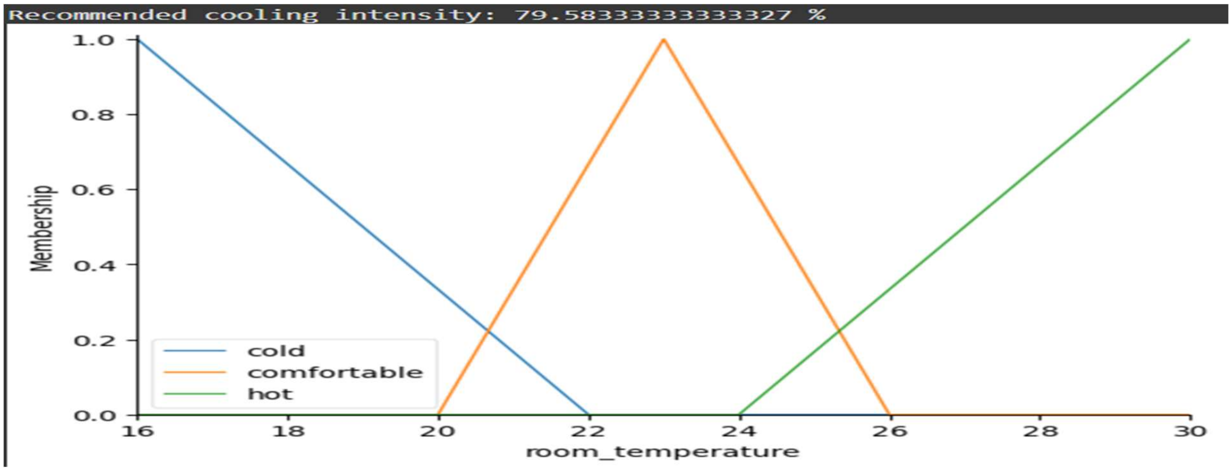
CODE:

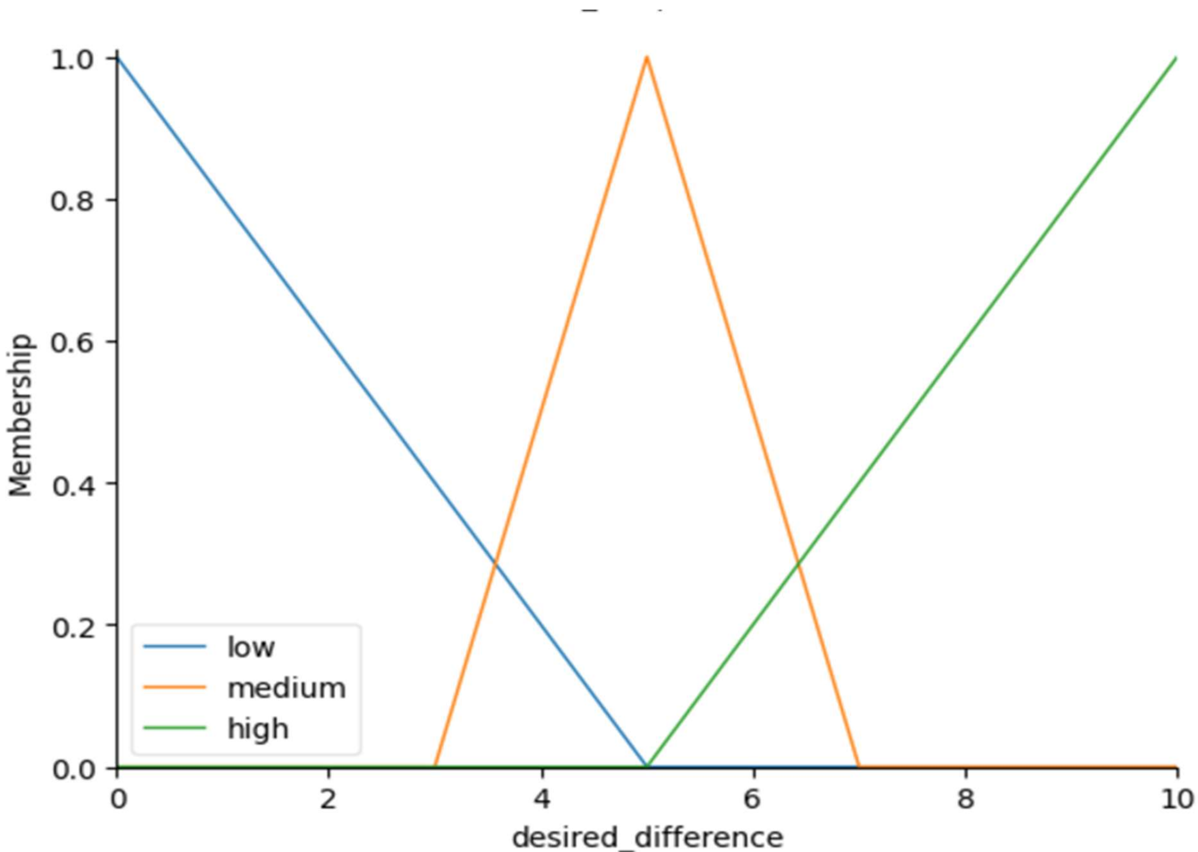
```
import numpy as np

import skfuzzy as fuzz

from skfuzzy import control as ctrl

# Step 1: Define fuzzy variables

room_temperature = ctrl.Antecedent(np.arange(16, 31, 1), 'room_temperature')  # Room
temperature in °C

desired_difference = ctrl.Antecedent(np.arange(0, 11, 1), 'desired_difference')  # Desired
temperature difference

cooling = ctrl.Consequent(np.arange(0, 101, 1), 'cooling')  # Cooling intensity in %

# Step 2: Define fuzzy membership functions

# Room temperature

room_temperature['cold'] = fuzz.trimf(room_temperature.universe, [16, 16, 22])

room_temperature['comfortable'] = fuzz.trimf(room_temperature.universe, [20, 23, 26])

room_temperature['hot'] = fuzz.trimf(room_temperature.universe, [24, 30, 30])

# Desired temperature difference

desired_difference['low'] = fuzz.trimf(desired_difference.universe, [0, 0, 5])

desired_difference['medium'] = fuzz.trimf(desired_difference.universe, [3, 5, 7])

desired_difference['high'] = fuzz.trimf(desired_difference.universe, [5, 10, 10])

# Cooling intensity

cooling['low'] = fuzz.trimf(cooling.universe, [0, 0, 50])

cooling['medium'] = fuzz.trimf(cooling.universe, [30, 50, 70])

cooling['high'] = fuzz.trimf(cooling.universe, [50, 100, 100])

# Step 3: Define fuzzy rules

rule1 = ctrl.Rule(room_temperature['cold'] & desired_difference['low'], cooling['low'])

rule2 = ctrl.Rule(room_temperature['cold'] & desired_difference['medium'], cooling['low'])
```

```
rule3 = ctrl.Rule(room_temperature['comfortable'] & desired_difference['low'], cooling['low'])

rule4 = ctrl.Rule(room_temperature['comfortable'] & desired_difference['medium'],
cooling['medium'])

rule5 = ctrl.Rule(room_temperature['hot'] & desired_difference['medium'], cooling['medium'])

rule6 = ctrl.Rule(room_temperature['hot'] & desired_difference['high'], cooling['high'])

# Step 4: Create and simulate the control system

ac_control = ctrl.ControlSystem([rule1, rule2, rule3, rule4, rule5, rule6])

ac_simulation = ctrl.ControlSystemSimulation(ac_control)

# Step 5: Provide inputs

ac_simulation.input['room_temperature'] = 28  # Current room temperature

ac_simulation.input['desired_difference'] = 7  # Desired temperature difference

# Step 6: Perform fuzzy inference

ac_simulation.compute()

# Output the result

print("Recommended cooling intensity:", ac_simulation.output['cooling'], "%")

# Optional: Visualize the results

room_temperature.view()

desired_difference.view()

cooling.view(sim=ac_simulation)
```

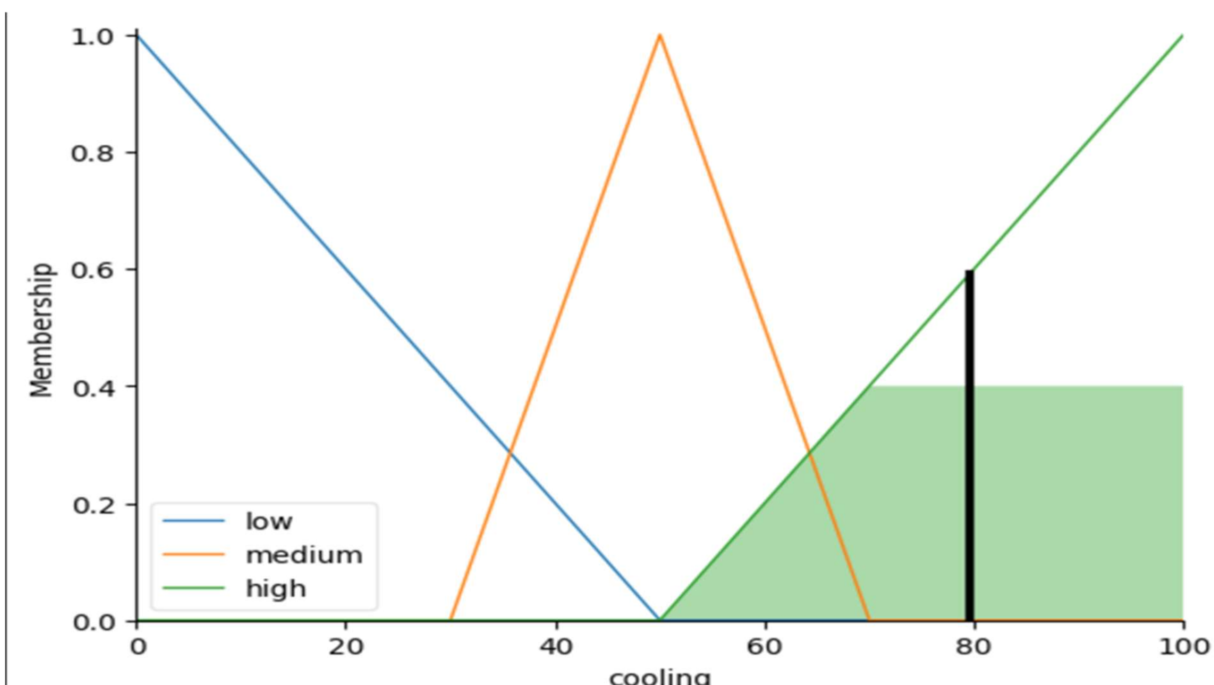
OUTPUT:

Recommended cooling intensity: 79.58333333333327 %





Membership
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
desired_difference
low
medium
high



Membership
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
cooling
low
medium
high

PROGRAM 10

AIM: Program to implement various Genetic operators like crossover, mutation and selection.

CODE:

```
import random

# Target solution

TARGET = "1010101010"

POPULATION_SIZE = 6

GENE_LENGTH = len(TARGET)

MUTATION_RATE = 0.1  # Probability of mutation (10%)

# Generate initial population

def generate_population(size, gene_length):

    return [''.join(random.choice("01") for _ in range(gene_length)) for _ in range(size)]

# Fitness function: Count matching bits with the target

def fitness(individual):

    return sum(1 for i, j in zip(individual, TARGET) if i == j)

# Selection: Roulette wheel selection

def selection(population, fitness_scores):

    total_fitness = sum(fitness_scores)

    probabilities = [score / total_fitness for score in fitness_scores]

    selected = random.choices(population, weights=probabilities, k=2)

    return selected

# Crossover: Single-point crossover

def crossover(parent1, parent2):

    crossover_point = random.randint(1, GENE_LENGTH - 1)

    offspring1 = parent1[:crossover_point] + parent2[crossover_point:]

    offspring2 = parent2[:crossover_point] + parent1[crossover_point:]
```

```
    return offspring1, offspring2
# Mutation: Flip a random bit
def mutate(individual):
    individual = list(individual)
    for i in range(len(individual)):
        if random.random() < MUTATION_RATE:
            individual[i] = '1' if individual[i] == '0' else '0'
    return ''.join(individual)
# Main Genetic Algorithm function
def genetic_algorithm():
    # Generate initial population
    population = generate_population(POPULATION_SIZE, GENE_LENGTH)
    generation = 0
    print(f"Generation {generation}: {population}")
    while True:
        # Evaluate fitness
        fitness_scores = [fitness(individual) for individual in population]
        # Check for target match
        if TARGET in population:
            print(f"Solution found in generation {generation}: {TARGET}")
            break
        # Selection
        new_population = []
        for _ in range(POPULATION_SIZE // 2):  # Produce pairs of offspring
            parent1, parent2 = selection(population, fitness_scores)
            # Crossover
            offspring1, offspring2 = crossover(parent1, parent2)
            # Mutation
```

```
            offspring1 = mutate(offspring1)
            offspring2 = mutate(offspring2)

            new_population.extend([offspring1, offspring2])
        # Update population
        population = new_population
        generation += 1
        print(f"Generation {generation}: {population}")
# Run the Genetic Algorithm
if __name__ == "__main__":
    genetic_algorithm()
```

OUTPUT:

```
Generation 0: ['0101100101', '0101000011', '1011100100', '1001101110', '0011101001', '1011011100']
Generation 1: ['1011111100', '1011011100', '0101000110', '1011100110', '1001101001', '0001101110']
Generation 2: ['1011011100', '1111011100', '1001101000', '0001101111', '1101100110', '0101000111']
Generation 3: ['1111000111', '0101011100', '1101001110', '1011011100', '0001000110', '1101101011']
Generation 4: ['0101011111', '1101101100', '1010010100', '1011011100', '1111000110', '1101001011']
Generation 5: ['0101101100', '1111001011', '1010011100', '1011010100', '1111101111', '1101001000']
Generation 6: ['1011111101', '1101001000', '1010001100', '1010001100', '1111001111', '1111101001']
Generation 7: ['1100111000', '1111001101', '1010000100', '1010000100', '1110001110', '1010001101']
Generation 8: ['0011001100', '1111000111', '1110010100', '0010001010', '1110000101', '1010000111']
Generation 9: ['1011000111', '1110011100', '1110100111', '1010000111', '0010001110', '0011011010']
Generation 10: ['1010011100', '1110000111', '0110010011', '1011000111', '1011000111', '1110100111']
Generation 11: ['0110010100', '1110011011', '1011000111', '1010100111', '1110110011', '0111101111']
Generation 12: ['1010101011', '1010100011', '1011110011', '1110000110', '1010100111', '0010100110']
Generation 13: ['1011100110', '0010110011', '1010100110', '0010110110', '1011111001', '1111110010']
Generation 14: ['1011100110', '0010100110', '1010100010', '1011110100', '0010110110', '0000100011']
Generation 15: ['1001100010', '1010100011', '1011100110', '0101100011', '1010100110', '1010110100']
Generation 16: ['1001100010', '1011100110', '1010110100', '1010100001', '1001100010', '1011000110']
Generation 17: ['1100100001', '0010110100', '1011000010', '1001100011', '1010001100', '1001100001']
Generation 18: ['1001100011', '1001100011', '1010100101', '1100100100', '0001100011', '1000010100']
Generation 19: ['0011000011', '1001100010', '1001101100', '1010010111', '0001100011', '1001100011']
Generation 20: ['0011100011', '1001000011', '1000000001', '0011100100', '0000100111', '1101100011']
Generation 21: ['1000000011', '0111100000', '1000100111', '0011100111', '0001100111', '1000000001']
Generation 22: ['0000010011', '1011110111', '0011100111', '0011100111', '1000000011', '1000000001']
Generation 23: ['0011010001', '1000100111', '0011100011', '1000001111', '0000010011', '1011110011']
Generation 24: ['0000010011', '0000100111', '1000001110', '1000010001', '1000001111', '1111110011']
Generation 25: ['1111101110', '1000010011', '0010010111', '0000100111', '1000001111', '1000001110']
Generation 26: ['0010010110', '1000000110', '1000010011', '0000110111', '1010010111', '0000001110']
Generation 27: ['0000001110', '0000001010', '0100000110', '1101001110', '1000001110', '0000010011']
Generation 28: ['0000001010', '1011101010', '0000101010', '0000001010', '0000101110', '0000001010']
Generation 29: ['0000001000', '1010101010', '0000100010', '0000001010', '0010001010', '0000001010']
Solution found in generation 29: 1010101010
```

PROGRAM 11

AIM: Program to implement Genetic Algorithm to maximize the objective function such as f(x)=x^2 where x can have values from 0 to 31.

CODE:

```
import random
# Parameters
POPULATION_SIZE = 6  # Number of individuals in the population
CHROMOSOME_LENGTH = 5  # Binary representation of x (5 bits for values 0 to 31)
MUTATION_RATE = 0.1  # Probability of mutation (10%)
GENERATIONS = 15  # Maximum number of generations
# Objective function
def objective_function(x):
    return x**2
# Generate initial population
def generate_population(size, length):
    return [''.join(random.choice("01") for _ in range(length)) for _ in range(size)]
# Decode binary chromosome to integer value
def decode(chromosome):
    return int(chromosome, 2)
# Fitness function
def fitness(chromosome):
    x = decode(chromosome)
    return objective_function(x)
# Selection: Roulette wheel selection
def selection(population, fitness_scores):
    total_fitness = sum(fitness_scores)
    probabilities = [score / total_fitness for score in fitness_scores]
```

```
    return random.choices(population, weights=probabilities, k=2)
# Crossover: Single-point crossover
def crossover(parent1, parent2):
    point = random.randint(1, CHROMOSOME_LENGTH - 1)
    offspring1 = parent1[:point] + parent2[point:]
    offspring2 = parent2[:point] + parent1[point:]
    return offspring1, offspring
# Mutation: Flip a random bit
def mutate(chromosome):
    chromosome = list(chromosome)
    for i in range(len(chromosome)):
        if random.random() < MUTATION_RATE:
            chromosome[i] = '1' if chromosome[i] == '0' else '0'
    return ''.join(chromosome)
# Main Genetic Algorithm function
def genetic_algorithm():
    # Generate initial population
    population = generate_population(POPULATION_SIZE, CHROMOSOME_LENGTH)
    generation = 0
    print(f"Generation {generation}: {population}")
    for _ in range(GENERATIONS):
        # Evaluate fitness
        fitness_scores = [fitness(chromosome) for chromosome in population]
        # Find and print the best solution
        best_chromosome = max(population, key=lambda chrom: fitness(chrom))
        best_x = decode(best_chromosome)
        best_fitness = fitness(best_chromosome)
        print(f"Best solution in generation {generation}: x = {best_x}, f(x) = {best_fitness}")
```

```
        # Selection
        new_population = []
        for _ in range(POPULATION_SIZE // 2):  # Produce pairs of offspring
            parent1, parent2 = selection(population, fitness_scores)
            # Crossover
            offspring1, offspring2 = crossover(parent1, parent2)
            # Mutation
            offspring1 = mutate(offspring1)
            offspring2 = mutate(offspring2)
            new_population.extend([offspring1, offspring2])
        # Update population
        population = new_population
        generation += 1
# Run the Genetic Algorithm
if __name__ == "__main__":
    genetic_algorithm()
```

OUTPUT:

```
Generation 0: ['10001', '10111', '01011', '01010', '00101', '11111']
Best solution in generation 0: x = 31, f(x) = 961
Best solution in generation 1: x = 31, f(x) = 961
Best solution in generation 2: x = 31, f(x) = 961
Best solution in generation 3: x = 31, f(x) = 961
Best solution in generation 4: x = 29, f(x) = 841
Best solution in generation 5: x = 31, f(x) = 961
Best solution in generation 6: x = 31, f(x) = 961
Best solution in generation 7: x = 30, f(x) = 900
Best solution in generation 8: x = 31, f(x) = 961
Best solution in generation 9: x = 31, f(x) = 961
Best solution in generation 10: x = 30, f(x) = 900
Best solution in generation 11: x = 30, f(x) = 900
Best solution in generation 12: x = 30, f(x) = 900
Best solution in generation 13: x = 31, f(x) = 961
Best solution in generation 14: x = 27, f(x) = 729
```