DEPARTMENT OF COMPUTER ENGINEERING & APPLICATIONS

Institute of Engineering & Technology

LAB MANUAL

Subject Name: Soft Computing Lab

Subject Code: BCSE0132

Submitted To:

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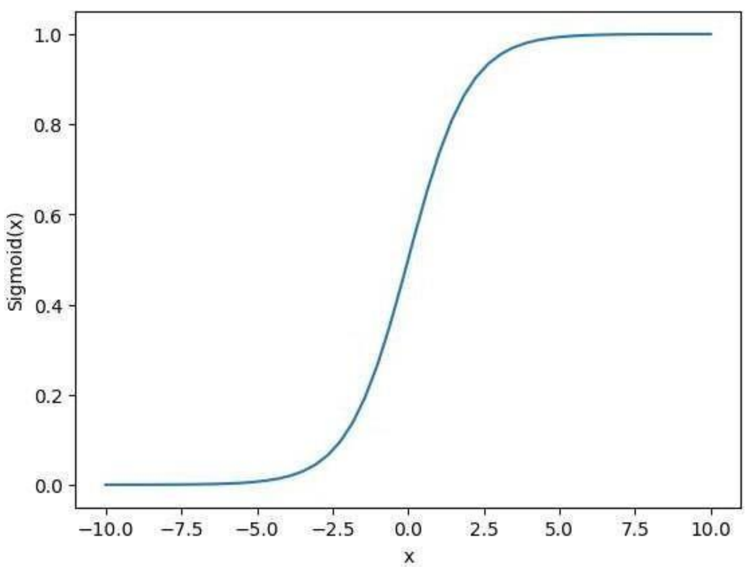
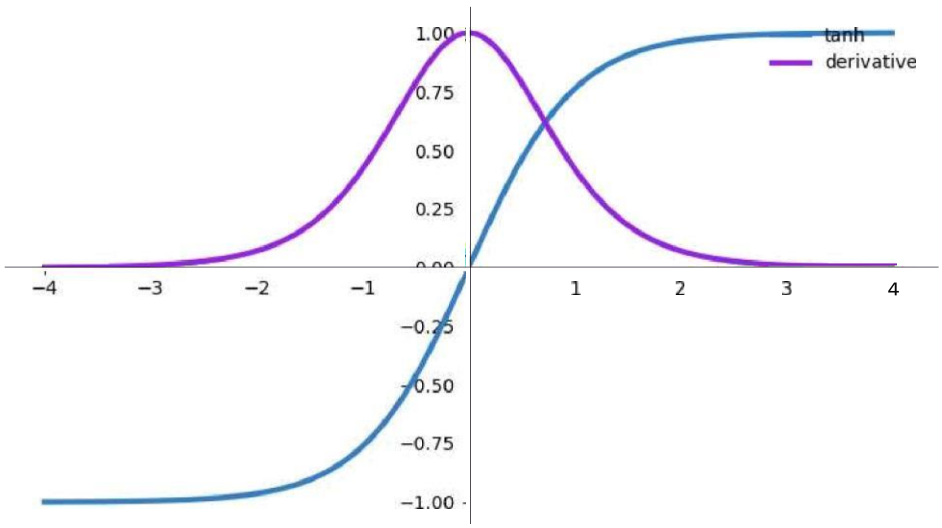
```
import numpy as np
def sig(x):
 return 1/(1 + np.exp(-x))


x = 1.0
print('Applying Sigmoid Activation on (%.1f) gives %.1f' % (x, sig(x)))

x = -10.0
print('Applying Sigmoid Activation on (%.1f) gives %.1f' % (x, sig(x)))

x = 0.0
print('Applying Sigmoid Activation on (%.1f) gives %.1f' % (x, sig(x)))

x = 15.0
print('Applying Sigmoid Activation on (%.1f) gives %.1f' % (x, sig(x)))

x = -2.0
print('Applying Sigmoid Activation on (%.1f) gives %.1f' % (x, sig(x)))


import numpy as np
import matp1ot1ib.pyplot as plt
x = np.1inspace(-10, 10, 50)
p = sig(x)
plt.xlabel("x")
plt.ylabel("Sigmoid(x)")
plt.plot(x, p)
plt.show()
```

```
Applying Sigmoid Activation on (1.0) gives 0.7
Applying Sigmoid Activation on (-10.0) gives 0.0
Applying Sigmoid Activation on (0.0) gives 0.5
Applying Sigmoid Activation on (15.0) gives 1.0
Applying Sigmoid Activation ou (-2.0) gives 0.1
```




```
#tanh or Hyperbo11c:
import matplotlib.pyplot as plt
import numpy as np

def tanh(x):
    t=(np.exp(x)-np.exp(-x))/(np.exp(x)+np.exp(-x))
    dt=1-t**2
    return t,dt
z=np.arange(-4,4,0.01)
tanh(z[0].size,tanhz)[I.size
# Setup centered axes
fig, ax = pit.subplots(figsize=(9, 5))
ax.spines['left'].set_position('center')
ax.spines['bottom'].set_position('center')
ax.spines['right'].set_color('none')
```

```
ax.spines['top'].set_co1or('none')
ax.xaxis.set ticks position('bottom')
ax.yaxis.set_ticks_position('left')
     a    a             t
 xCpe tez   dnhh w[pl, color="#307EC7", linewidth=3, label="tanh")
ax.plot(z,tanh(z)[1], color="#9621E2", linewidth=3, label="derivative")
ax.legend(loc="upper right", frameon=Fa1se)
fig.show()
```

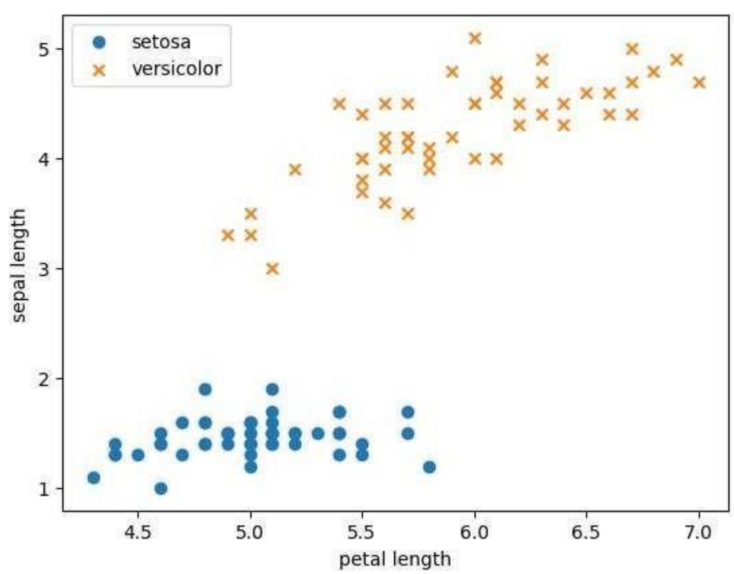


- To write aprogram to create aperceptron network using command 'newp'

```
#@title To write a program to create a perceptron network using command 'newp'
#Iguore this command as it belongs to Matlab


import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
def load_data():
    URL_='https://archive.ics.uci.edu/ml/machine-learning-databases/iris/iris.data'
    data = pd.read_csv(URL_, header = None)
    priut(data)

    # make the dataset linearly separable
    data = data[:l00]
    data[4] = np.where(data.iloc[:, -1]=='Iris-setosa', 0, 1)
    data = np.asmatrix(data, dtype = 'float64')
    return data
data = load_data()
```

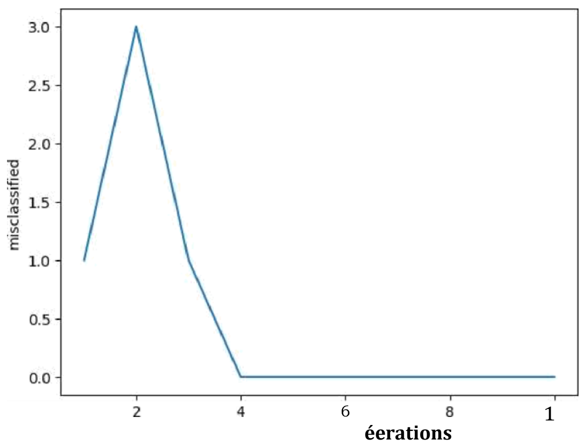
```
         0    1    2    3              4
0      5.1  3.5  1.4  0.2    Iris-setosa
1      4.9  3.0  1.4  0.2    Iris-setosa
2      4.7  3.2  1.3  0.2    Iris-setosa
3      4.6  3.1  1.5  0.2    Iris-setosa
4      5.0  3.6  1.4  0.2    Iris-setosa

145    6.7  3.0  5.2  2.3  Ir1s-v1rg1n1ca
146    6.3  2.5  5.0  1.9  Ir1s-v1rg1n1ca
147    6.5  3.0  5.2  2.0  Iris-v1tg11ca
148    6.2  3.4  5.4  2.3  Ir1s-v1rg1n1ca
149    5.9  3.0  5.1  1.8  Ir1s-v1rg1n1ca

[150 rows x 5 columns]
```

```
plt.scatter(np.array(data[:50,0]), np.array(data[:50,2]), marker='o', label='setosa')
plt.scatter(np.annay(data[50:,0]), np.annay(data[50:,2]), manken='x', label='versicolon')
plt.xlabel('petal length')
plt.ylabel('sepal length')
plt.legend()
plt.show()
```




```
def perceptron(data, num_iter):
    features = data[:, :-1]
    labels = data[:, -1]

    # set weights to zero
    w = np.zeros(shape=(1, features.shape[I]+1))

    misclassified_ = []
```

```
        for epoch in range(num_iter):
            misclassified = 0
            for x, label in zip(features, labels):
                x = np.insert(x,0,1)
                y = np.dot(w, x.transpose())
                target = 1.0 if (y > 0) else 0.0

                delta = (label.item(0,0) - target)

                if(delta): # misclassified
                    misclassified += 1
                    w += (delta * x)

            misclassified_.append(misclassified)
        return (w, misclassified_)

    num_iter = 10
    w, misclassified_ = perceptron(data, num_iter)


    epochs = np.arange(1, num_iter+1)
    p1t.p1ot(epochs, misclassified_)
    plt.xlabel('iterations')
    plt.ylabel('misclassified')
    plt.show()
```



- To implement single perceptron

```
#@title To implement single perceptron



import numpy as np
import pandas as pd


data=pd.read_csv('Iris.csv')
data.columns=['Sepal_len_cm','Sepal_wid_cm','Petal_len_cm','Petal_wid_cm','Type']
data.head(10)
```

	Sepal_len_cm	Sepal_wid_cm	Petal_len_cm	Petal_wid_c
0	4.9	3.0	1.4	0.
1	4.7	3.2	1.3	0.
2	4.6	3.1	1.5	0.
3	5.0	3.6	1.4	0
4	5.4	3.9	1.7	0
5	4.6	3.4	1.4	0.
6	5.0	3.4	1.5	0
7	4.4	2.9	1.4	0.
8	[illegible]	[illegible]	[illegible]	[illegible]
9				

- Use Sigmoid function as the activation function

```
#@title Use Sigmoid function as the activation function


def activation_func(value): #Tangent Hypotenuse
    #return (1/(1+np.exp(-value)))
    return  ((np.exp(value)-np.exp(-value))/(np.exp(value)+np.exp(-value)))


def perceptron_train(in_data,labels,alpha):
    X=np.array(in_data)
    y=np.array(labels)
    weights=np.random.random(X.shape[1])
    original=weights
    bias=np.random.random_sample()
    for key in range(X.shape[0]):
        a=activation_func(np.matmul(np.transpose(weights),X[key]))
        yu=0
        if a>=0.7:
            yn=1
        elif a<=(-0.7):
            yn=-1
        weights=weights+alpha*(yn-y[key])*X[key]
        print('Iteration '+str(key)+': '+str(weights))
    print('Difference: '+str(weights-original))
    return weights
```

- Testing and Score

```
#@title Testing and Score


def perceptron_test(in_data,label_shape,weights):
    X=np.array(in_data)
    y=up.zeros(label_shape)
    for key in range(X.shape[1]):
        a=activation_func((weights*X[key]).sum())
        y[key]=0
        if a>=0.7:
```

```
            y[key]=1
        e11f a‹=(-0.7):
            y[key]=-1
    return y


def score(result,labels):
    difference=result-np.array(labels)
    correct_ctr=0
    for elem in range(difference.shape[0]):
        if difference[elem]==0:
            correct_ctr+=1
    score=correct_ctr*100/difference.size
    print('Score='+str(score))


#@ Main code


# Dividiug DataFrame “data“ into “d_traiu“ (60%) and “d_test“ (40%)
divider = np.random.rand(len(data)) ‹ 0.70
d_train=data[divider]
d_test=data[-divider]


# Dividing d_train into data and labels/targets
d_traiu_y=d_train['Type']
d_train_X=d_train.drop(['Type'],axis=1)

# Dividing d_train into data and labels/targets
d_test_y=d_test['Type']
d_test_X=d_test.drop(['Type'],axis=1)


# Learning rate
alpha = 0.01

# Train
weights = perceptron_train(d_train_X, d_train  , alpha)
```

```
    Iteration 0: [0.62085819 0.24880642 0.49123374 0.11735
    Iteration 1: [0.66785019 0.28080642 0.50423374 0.11935
    Iteration 2: [0.71785019 0.31680642 0.51823374 0.12135
    Iteration 3: [0.76785019 0.35080642 0.53323374 0.12335
    Itenation 4: [0.81685019 0.38180642 0.54823374 0.12435
    Iteration 5: [0.87085019 0.41880642 0.56323374 0.12635
    Iteration 6: [0.91885019 0.45280642 0.57923374 0.12835
    Iteration 7: [0.96685019 0.48280642 0.59323374 0.12935
    Iteration 8: [1.02485019 0.52280642 0.60523374 0.13135
    Iteration 9: [1.08185019 0.56680642 0.62023374 0.13535
    Iteration 10: [1.13585819  0.60580642 0.63323374 0.139
    Iteration 11: [1.18685019  0.64080642 0.64723374 0.142
    Iteration 12: [1.23785019  8.67880642 0.66223374 0.145
    Iteration 13: [1.28885019  0.71580642 0.67723374 0.149
    Iteration 14: [1.33485019  8.75180642 0.68723374 0.151
    Iteration 15: [1.38585019  0.78480642 0.70423374 0.156
    Iteration 16: [1.43385019  0.81880642 0.72323374 0.158
    Iteration 17: [1.48385019  0.84880642 0.73923374 0.160
    Iteration 18: [1.53585019  8.88380642 0.75423374 0.162
    Iteration 19: [1.58785019  0.91780642 0.76823374 0.164
    Iteration 20: [1.63485019  0.94980642 0.78423374 0.166
    Iteration 21: [1.68885019  0.98380642 0.79923374 0.170
    Iteration 22: [1.74085019  1.02480642 0.81423374 0.171
    Iteration 23: [1.79585019  1.06680642 0.82823374 0.173
    Iteration 24: [1.84485019  1.09780642 0.84323374 0.174
    Iteration 25: [1.89485019  1.12980642 0.85523374 0.176
    Iteration 26: [1.94985019  1.16480642 0.86823374 0.178
    Iteration 27: [1.99885019  1.19580642 0.88323374 0.179
    Iteration 28: [2.04285019  1.22580642 0.89623374 B.181
    Iteration 29: [2.09285019  1.26080642 0.90923374 B.184
    Iteration 30: [2.13685019  1.29280642 0.92223374 8.186
    Iteration 31: [2.18685019  1.32780642 0.93823374 0.192
    Iteration 32: [2.23785019  1.36580642 0.95423374 0.194
    Iteration 33: [2.29085019  1.40280642 0.96923374 0.196
    Iteration 34: [2.34085019  1.43580642 0.98323374 0.198
    Iteration 35: [2.48085019  1.49980642 1.07723374 0.226
    Iteration 36: [2.61885019  1.56180642 1.17523374 0.256
```

```
Iteration 42: [3.31485019 1.87780642 1.66323374 0.40435913]
Iteration 43: [3.44885019 1.93980642 1.75123374 0.43235913]
Iteration 44: [3.56085019 1.99980642 1.84123374 0.46235913]
Iteration 45: [3.67685019 2.05380642 1.92323374 0.48235913]
Iteration 46: [3.78885019 2.10380642 2.00123374 0.50435913]
Iteration 47: [3.90685019 2.16780642 2.09723374 0.54035913]
Iteration 48: [4.03285019 2.21780642 2.19523374 0.57035913]
Iteration 49: [4.15485019 2.27380642 2.28923374 0.59435913]
Iteration 50: [4.29085019 2.32980642 2.38523374 0.62235913]
Iteration 51: [4.42485019 2.38980642 2.48523374 0.65635913]
Iteration 52: [4.53885019 2.44180642 2.55523374 0.67635913]
Iteration 53: [4.64885019 2.48980642 2.63123374 0.69835913]
Iteration 54: [4.75885019 2.53780642 2.70523374 0.71835913]
Itenation 55: [4.87485019 2.59180642 2.78323374 0.74235913]
Iteration 56: [4.99485019 2.65980642 2.87323374 0.77435913]
Iteration 57: [5.12885019 2.72180642 2.96723374 0.80435913]
```

- To implement OR and AND functions using ADALINE with bipolar inputs and output

```
#@title To implement OR and AND functions using ADALINE with bipolar inputs and output
#https://www.geeksforgeeks.org/implemeutiug-audnot-gate-usiug-adaline-network/
```

- OR gate implementation

```
#@title OR gate implementation
import numpy as np

# Define the Adaline class
class AdalineGD(object):
    def finite(self, learning_rate=0.01, n_iter=50):
        self.learnin rate = learning_rate
        self.n_iter = n_iter

    def fit(self, X, y):
        self.weights_ = np.zeros(1 + X.shape[1])
        self.cost_ = []

        for i in range(self.n_iter):
            output = self.net_input(X)
            errors = (y - output)
            self.weights_[1:] += self.learning_rate * X.T.dot(errors)
            self.weights_[0] += self.learuiug_rate * errors.sum()
            cost = (errors**2).sum() / 2.0
            self.cost_.append(cost)
        neturn self

    def uet_input(self, X):
        return np.dot(X, self.weights_[1:]) + self.weights_[0]

    def activation(self, X):
        return self.net_input(X)

    def predict(self, X):
        return np.where(self.activation(X) >= 0.0, 1, 0)

# Define the OR gate input and outputs
X = np.array([[0, 0],
              [0, 1],
              [1, 0],
              [1, 1]l)

y = np.array([0, 1, 1, 1])

# Create the Adaline and train it
adaline = AdalineGD(learning_rate=0.01, n_iter=10)
adaline.fit(X, y)

# Test the Adaline network
print(“Pnedictions:“)
for xi in X:
    print(xi, "-›", adaline.predict(xi))
```

```
Predictions:

[8 l] -> 1

[1 l] -> 1
```

- AND gate implementation

```
#@title AND gate implementation
import numpy as np

                             a
clDes' datheeAD ob ec l
    def finite(self, learning_rate=0.01, n_iter=50):
            ea pn   ’’    earnin rate
        self n  te    n ee

    def fit(self, X, y):
```

```
        self.weights_ = np.zeros(1 + X.shape[1
        self.cost_ = []

        for i in rauge(self.n_iter):
            output = self.net_input(X)
            errors = (y - output)
            self.weights_[1:] += self.learning_rate * X.T.dot(errors)
            self.weights_[0] += self.learning_rate * errors.sum()
            cost = (errors**2).sum() / 2.0
            self.cost_.append(cost)
        return self

    def net_input(self, X):
        return np.dot(X, self.weights_[1:]) + self.weights_[0]

    def activation(self, X):
        return self.net_iuput(X)

    def predict(self, X):
        return np.where(self.activation(X) ›= 0.0, 1, 0)

# Define the OR gate input and outputs
X = np.array([[0, 0],
              [0, 1],
              [1, 0],
              [1, 1]1)

y = up.array([0, 0, 0,1])

    e   e
ad    e    daAd eGDel  dn naina e=0.01, n_iter=10)
adaline.fit(X, y)

# Test the Adaline network
print("Predictions:")
for xi in X:
    print(xi, "-›", adaline.predict(xi))
```

- Backpropagation algorithm with multilayer perceptron network

```
#@title Backpropagation algorithm with multilayer perceptron network



from math import exp
from random import seed
from random import random

# Initialize a network
def initialize_network(u_iuputs, n_hidden, n_outputs):
  network = list()
  hidden_layer = [{'weights':[random() for i in range(n_inputs + 1)]} for i in range(n_hidden)]
  network.append(hidden_layer)
  output_layer = [{'weights':[random() for i in range(n_hidden + 1)]} for i in rauge(n_outputs)]
  network.append(output_layer)
  returu network

# Calculate neuron activation for an input
def activate(weights, inputs):
  activation = weights[-1]
  for i in range(len(weights)-1):
    activation += weights[i] * inputs[i]
  return activation

# Transfen neunon activation
def transfer(activation):
  returu 1.0 / (1.0 e exp(-activation))

# Forward propagate input to a network output
def forward_propagate(network, row):
  inputs = row
  for layer in network:
    uew_iuputs = []
    for neuron in layer:
      activation = activate(neuron['weights'], inputs)
      neuron['output'] = transfer(activation)
      new_inputs.append(neuron['output'])
    inputs = new_inputs
  return inputs

# Calculate the derivative of an neuron output
def transfer_derivative(output):
  netunn output * (1.0 - output)

# Backpropagate error and store in neurons
def backward_propagate_error(network, expected):
  for i in reversed(range(len(network))):
    layer = network[i]
    ennons = list()
    if i != len(network)-1:
      for j in range(leu(layer)):
        error = 0.0
        for neuron in network[i   1]:
          ennon += (neunon['weights'][j] s neuron['delta'])
        errors.append(ennon)
    else:
      for j in range(leu(layer)):
        neuron = layer[j]
        errors.append(neuron['output'] - expected[j])
    for j in range(len(layer)):
      neuron = layer[j]
      neuron['delta'] = errors[j] * transfer_derivative(neuron['output'])

# Update network weights with error
def update_weights(network, row, l_rate):
  for i in range(len(network)):
    inputs = row[:-1]
    if i != 0:
      inputs = [neuron['output'] for neuron in network[i - 1]]
    for neuron in network[i]:
      for j in range(len(inputs)):
        neuron['weights'][j] -= l_rate * neuron['delta'] * inputs[j]
      neuron['weights'][-1] -= l_rate * neuron['delta']
```

```
# Train a network for a fixed number of epochs
def tnain_network(network, train, l_rate, n_epoch, n_outputs):
  for epoch in range(n_epoch):
    sum_error   =   0
    for now in train:
      outputs = forward_propagate(network, row)
      expected = [B for i in range(n_outputs)]
      expected[row[-1]] = 1
      sum_error += sum([(expected[i]-outputs[i])**2 for i in range(len(expected))])
      backward_propagate_error(network, expected)
      update_weights(network, row, l_rate)
    print('>epoch=%d, lrate=%.3f, error=%.3f' % (epoch, l_rate, sum_error))

# Test training backprop algorithm
seed(1)
dataset = [[2.7810836,2.550537003,0],
 [1.465489372,2.362125076,0],
 [3.396561688,4.400293529,0],
 [1.38807019,1.850220317,0],
 [3.06407232,3.005305973,0],
 [7.627531214,2.759262235,1],
 [5.332441248,2.088626775,1],
 [6.922596716,1.77106367,1],
 [8.675418651,-0.242068655,1],
 [7.673756466,3.508563011,1]]
 n_inputs = len(dataset[0]) - 1
n_outputs = len(set([row[-I] for row in dataset]))
network = initialize_network(n_inputs, 3, n_outputs)
train_network(network, dataset, 0.5, 20, n_outputs)
for layer in network:
  print(layer)
```

```
>epoch=0, lrate=0.50B, error=6.880
>epoch=l, 1rate=0.500, error=5.740
>epoch=2, lrate=0.500, error=5.326
>epoch=3, lrate=0.500, error=5.338
>epoch=4, lrate=0.500, error=5.299
>epoch=5, lrate=0.500, error=5.136
>epoch=6, lrate=0.500, error=4.924
>epoch=7, lrate=0.500, error=4.692
>epoch=8, lrate=0.500, error=4.419
>epoch=9, lrate=0.500, error=4.112
>epoch=10, lrate=0.500, error=3.785
>epoch=ll, lrate=0.500, error=3.456
>epoch=12, lrate=0.500, error=3.138
>epoch=13, 1rate=0.500, error=2.838
>epoch=14, lrate=0.500, enron=2.563
>epoch=15, lrate=B.5BB, error=2.313
>epoch=16, lrate=0.500, error=2.089
>epoch=17, lrate=0.500, error=1.889
>epoch=18, lrate=0.50B, error=1.710
>epoch=19, lrate=0.500, error=1.552
[{'weights': [0.2663982735658251, 0.7860076057871438, 0.7603367533444867], 'output': 0.9961594902966306, 'delta': -0.00011266901222636lf
[{'weights': [-0.7317965482405842, 2.3716621057165623, -0.5690560485083125, -0.03474552839897625], 'output': 0.23494719808744585, 'delt‹
```

- Program for fuzzy set with properties and operations.

```
#@title Program for fuzzy set with properties and operations.
```

Example to Demonstrate the Union of Two Fuzzy Sets

```
#@title Example to Demonstrate the Union of Two Fuzzy Sets
A = dict()
B = dict()
Y = dict()

A = {”a“: 0.2, "b": 0.3, “c“: B.6, “d“: 0.6}
B = {”a”: 0.9, "b": 0.9, “c“: 0.4, “d“: 0.5}

print('The First Fuzzy Set is :', A)
print('The Second Fuzzy Set is :', B)


for A_key, B_key in zip(A, B):
  A_value = A[A_key]
  B_value = B[B_key]

  if A_value > B_value:
    Y[A_key] = A_value
  else:
    Y[B_key] = B_value

print(’Fuzzy Set Union 1s :', Y)
```

```
The First Fuzzy Set is : {'a': 0.2, 'b': 0.3, 'c': 0.6, 'd': 0.6}
The Second Fuzzy Set is : {'a': 0.9, 'b': 0.9, 'c': 0.4, 'd': 0.5}
Fuzzy Set Union is : {'a': 0.9, 'b': 0.9, 'c': 0.6, 'd': 0.6}
```

Example to Demonstrate Intersection of Two Fuzzy Sets

```
#@title Example to Demonstrate Intersection of Two Fuzzy Sets
A = dict()
B = dict()
Y = dict()

A = {”a”: 0.2, "b": 0.3, “c“: 0.6, “d“: 0.6}
B = {”a“: 0.9, "b": 0.9, “c“: 0.4, “d“: 0.5}

print('The First Fuzzy Set is :', A)
print('The Second Fuzzy Set is :', B)


for A_key, B_key in zip(A, B):
    A_va1ue = A[A_key]
    B_value = B[B_key]

    if A_value ‹ B_value:
        Y[A_key] = A_value
    else:
        Y[B_key] = B_value
print('Fuzzy Set Intersection is :', Y)
```

```
The First Fuzzy Set is : {'a': 0.2, 'b': 0.3, 'c': 0.6, 'd': 0.6}
The Second Fuzzy Set is : {'a': 0.9, 'b': 0.9, 'c': 0.4, 'd': 0.5}
Fuzzy Set Intersection is : {'a': 0.2, 'b': 0.3, 'c': 0.4, 'd': 0.5}
```

- Example to Demonstrate the Difference Between Two Fuzzy Sets

```
#@title Example to Demonstrate the Difference Between Two Fuzzy Sets
A = dict()
Y = dict()

A = {”a”: 0.2, "b": 0.3, “c“: 0.6, “d“: 0.6}

print('The Fuzzy Set is :', A)
```

```
for A_key in A:
  Y[A_key]= 1-A[A_key]

print('Fuzzy Set Complement is :', Y)
```

```
The Fuzzy Set is : {'a': 0.2, 'b': 0.3, 'c': 0.6, 'd': 0.6}
Fuzzy Set Complement is : {'a': 0.8, 'b': 0.7, 'c': 0.4, 'd': 0.4}
```

- Example to Demonstrate the Difference Between Two Fuzzy Sets

```
#@title Example to Demonstrate the Difference Between Two Fuzzy Sets
A = dict()
B = dict()
Y = dict()

A = {”a”: 0.2, "b": 0.3, “c“: 0.6, “d“: 0.6}
B = {”a”: 0.9, "b": 0.9, “c“: 0.4, “d“: 0.5}

print('The First Fuzzy Set is :', A)
print('The Second Fuzzy Set is :', B)


for A_key, B_key in zip(A, B):
  A_value = A[A_key]
  B_va1ue = B[B_key]
  B_value = 1 - B_value

  if A_value ‹ B_value:
    Y[A_key] = A_value
  else:
    Y[B_key] = B_value

print('Fuzzy Set Difference is :', Y)
```

```
The First Fuzzy Set is : {'a': 0.2, 'b': 0.3, 'c': 0.6, 'd': 0.6}
The Second Fuzzy Set is : {'a': 0.9, 'b': 0.9, 'c': 0.4, 'd': 0.5}
Fuzzy Set Difference is : {'a': 0.09999999999999998, 'b': 0.09999999999999998, 'c': 0.6, 'd': 0.5}
```

- Program for composition on Fuzzy and Crips relations

```
#@title Program for composition on Fuzzy and Crips relations


Inport numpy as np

# Max-Min Composition given by Zadeh
def maxN1n(x, y):

    I-or x1 In x:
        for y1 in y.T:
            z . append(max(np . minimum(xl, yl) ) )
    return np . array(z) . reshape( (x. shape[0] , y. shape[1] ) )

# Max-Product Composition given by Roseufeld
de-F- maxProduct (x, y) :

    for x1 In x:
        for y1 in y.T:
            z.append(max(np.multiply(x1, yl)))
    return np.array(z).reshape((x.shape[0], y.shape[1]))

# 3 arrays for the example
r1 = np.array([[1, 0, .7], [.3, .2, 0], [0, .5, 1]])
r2 = np.array([[.6, .6, 0], [0, .6, .1], [0, .l, 0]])
r3 = np.annay([[1, 0, .7], [0, 1, 0], [.7, 0, 1]])

print ("R1oR2 => Max-M1n :\n" + str(maxM1n(r1, r2) ) + "\n")
print ("R1oR2 => Max-Product :\n" + str(maxProduct(r1, r2) ) + "\n\n")

print ("R1oR3 => Nax-N1n :\n" + str(rraxH1n(r1, r3) ) + "\n")
print (“R1oR3 => Max-Product :\n“ + str(maxProduct(r1, r3)) + "\n\n")

print ("R1oR2oR3 => Max-M1n :\n" + st r(maxMln (r1, maxMln(r2, r3) ) ) + "\n" )
print (“RloR2oR3 => Max-Product :\n” + str(maxProduct(rl, maxProduct(r2, r3))) + ”\n\n")
```

```
R1oR2 => Max-M1n
[[0.6 0.6 0. ]
 [0.3 0.3 0.1]
 [0.  0.5 0.1]]

R1oR2 => Max-Product :
[[0.6  0.6  0.  ]
 [0.18 0.18 0.02]
 [0.   0.3  0.05]]


RloR3 => Max-Min :
[[1.  0.  0.7]
 [0.3 0.2 0.3]
 [0.7 0.5 1. ]]

R1oR3 => Max-Product :
[[1.   0.   0.7 ]
 [0.3  0.2  0.21]
 [0.7  0.5  1.  ]]


R1oR2oR3 => Max-M1n :
[[0.6 0.6 0.6]
 [0.3 0.3 0.3]
 [0.1 0.5 0.1]]

R1oR2oR3 => Max-Product :
[[0.6   0.6   0.42 ]
 [0.18  0.18  0.126]
 [0.035 0.3   0.05 ]]
```

- Example of Defuzzification operation

```
#@title Example of Defuzzification operation
```

```
!pip install -U scikit-fuzzy
```

```
Collecting scikit-fuzzy
  Downloading scikit-fuzzy-0.4.2.tar.gz (993 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 994.0/994.0 kB 6.5 MB/s eta 0:00:00
  Preparing metadata (setup.py) ... done
Requirement already satisfied: numpy>=1.6.0 in /usr/local/lib/python3.10/dist-packages (from scikit-fuzzy) (1.25.2)
Requirement already satisfied: scipy>=0.9.0 in /usr/local/lib/python3.10/dist-packages (from scikit-fuzzy) (1.11.4)
Requirement already satisfied: networkx>=1.9.0 in /usr/local/lib/python3.10/dist-packages (from scikit-fuzzy) (3.3)
Building wheels for collected packages: scikit-fuzzy
  Building wheel for scikit-fuzzy (setup.py) ... done
  Created wheel for scikit-fuzzy: filename=scikit_fuzzy-0.4.2-py3-none-any.whl size=894078 sha256=5de7ba1f887f7a65c1a8d49aed3f53cbbfa93:
  Stored in directory: /root/.cache/pip/wheels/4f/86/lb/dfd97l34a2c83l3e5l9bcebd95d3fedc7be7944db022094bc8
Successfully built scikit-fuzzy
Installing collected packages: scikit-fuzzy
Successfully installed scikit-fuzzy-0.4.2
```

```
import Humpy as np
import matplotlib.pyplot as plt
import skfuzzy as fuzz
```

```
# Generate trapezolda1 nenbershlp +unct1on on range [0, 1]
x = np. arange (0, 5. 05, 0. i)
mlx = fuzz.trapmf(x, [2, 2.5, 3, 4.5])
```

```
# Defuzzify this membership function five ways
defuzz_centroid = fuzz.defuzz(x, mfx, 'centroid') # Same as skfuzzy.centroid
defuzz_bisector = fuzz.defuzz(x, mfx, 'bisector')
defuzz_mom = fuzz.defuzz(x, mfx, 'mom')
defuzz_som = fuzz.defuzz(x, mfx, 'som')
defuzz_1om = fuzz.defuzz(x, mfx, '1om')
```

```
defuzz_som
```

```
2.5
```

```
# Collect info for vertical lines
labels = ['centroid', 'bisector', 'meau of maximum', 'miu of maximum',
          'max of maximum']
xvals = [defuzz_centroid,
         defuzz_bisector,
         defuzz_mom,
         defuzz_som,
         defuzz_lom]
colors = ['r', 'b', 'g', 'c', 'm']
ymax = [fuzz.interp_membership(x, mfx, i) for i in xvals]
```

```
defuzz_som
```

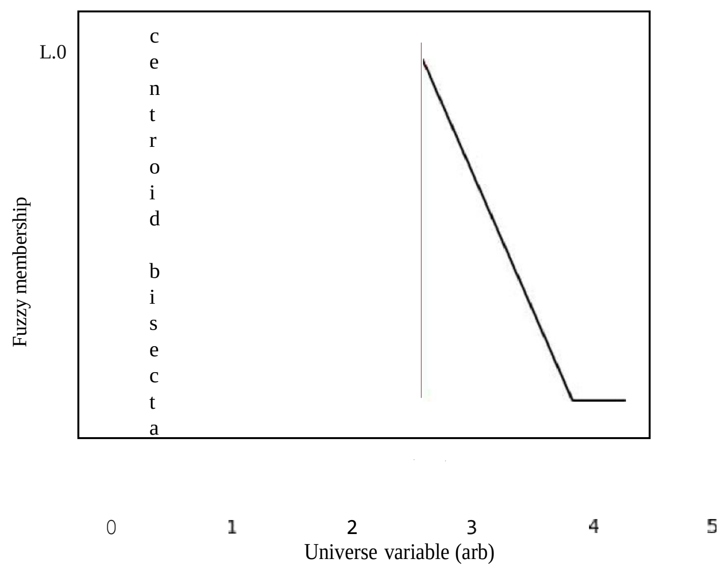
```
2.5
```

```
plt.figure(figsize=(12, 8))
```

```
<Figure size 1200x800 with 0 Axes>
<Figure size l200x800 with 0 Axes>
```

```
plt.plot(x, mfx, 'k')
for xv, y, label, color in zip(xvals, ymax, labels, colors):
    plt.vlines(xv, 0, y, label=label, color=color)
plt.ylabel('Fuzzy membership')
plt.xlabe1('Universe variable (arb)')
```

```
plt.ylim(-0.1, 1.1)

plt.legeud(loc=2)

plt.show()
```

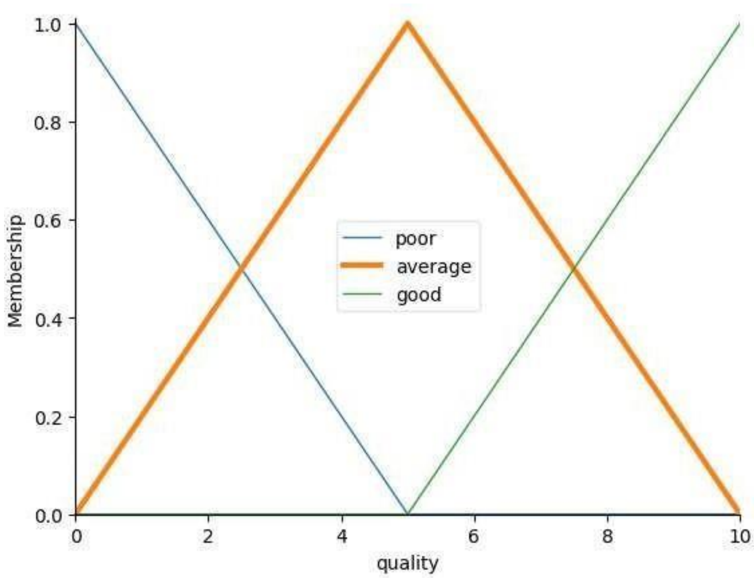


- Program for design of fuzzy inference system using membership funtion

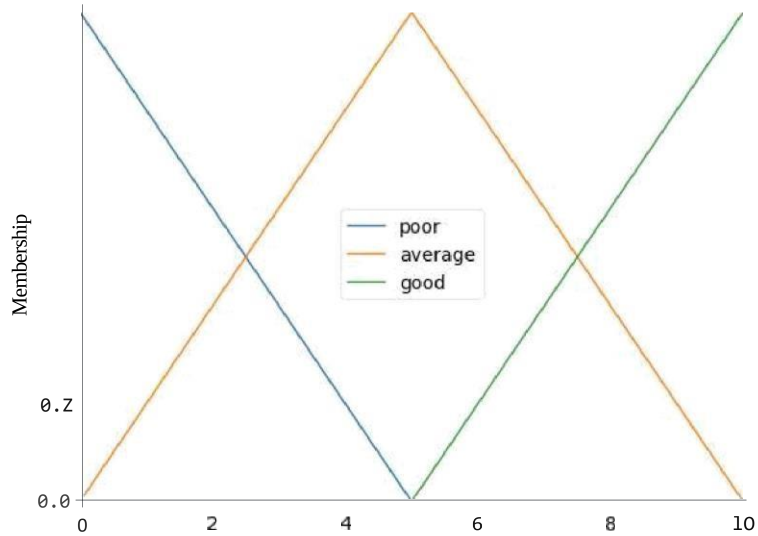
```
#@title Program for design of fuzzy inference system using membership funtion


pip install scikit-fuzzy scikit-learn
```

```
Collecting scikit-fuzzy
  Downloading scikit-fuzzy-0.4.2.tar.gz (993 kB)
     ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 994.0/994.0 kB 8.1 MB/s eta 0:00:00
  Preparing metadata (setup.py) ... doue
Requirement already satisfied: scikit-learn in /usr/local/lib/python3.10/dist-packages (1.2.2)
Requirement already satisfied: numpy›=1.6.0 in /usn/local/lib/python3.10/dist-packages (from scikit-fuzzy) (1.25.2)
Requirement already satisfied: scipy›=0.9.0 in /usr/local/lib/python3.10/dist-packages (from scikit-fuzzy) (1.11.4)
Requirement already satisfied: networkx>=1.9.0 in /usr/local/lib/python3.10/dist-packages (from scikit-fuzzy) (3.3)
Requirement already satisfied: joblib›=1.1.1 in /usr/local/lib/python3.10/dist-packages (from scikit-learn) (1.4.0)
Requirement already satisfied: threadpoolctl›=2.B.0 iu /usr/local/lib/pythou3.10/dist-packages (from scikit-learn) (3.4.0)
Building wheels for collected packages: scikit-fuzzy
  Building wheel for scikit-fuzzy (setup.py) ... doue
  Created wheel for scikit-fuzzy: filename=scikit_fuzzy-0.4.2-py3-none-any.wh1 size=894078 sha256=b921463f4a4ecfe655442cb493e9bc55fdc57J
  Stored in directory: /root/.cache/pip/wheels/4f/86/1b/dfd97134a2c8313e519bcebd95d3fedc7be7944db022094bc8
Successfully built scikit-fuzzy
Installing collected packages: scikit-fuzzy
Successfully installed scikit-fuzzy-0.4.2
```

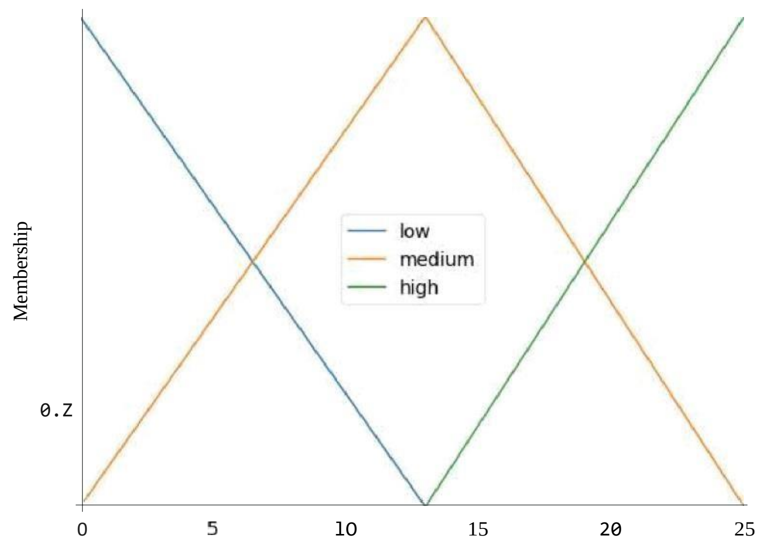
```
import numpy as np
import skfuzzy as fuzz
from skfuzzy import contnol as ctrl

# New Antecedent/Consequent objects hold universe variables aud membership
# functions
quality = ctrl.Antecedent(np.arange(0, 11, 1), 'quality')
service = ctrl.Antecedent(np.arange(0, 11, 1), 'service')
tip = ctrl.Consequent(np.arange(0, 26, 1), 'tip')

# Auto-membership function population is possible with .automf(3, 5, or 7)
quality.automf(3)
service.automf(3)

# Custom membership functions can be built interactively with a familiar,
# Pythonic API
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])


# You can see how these look with .view()
quality['average'].view()
```




```
service.view()
```




```
tip.view()
```




```
rulel = ctrl.Rule(quality['poor'] | service['poor'], tip['low'])
rule2 = ctrl.Rule(service['average'], tip['medium'])
rule3 = ctrl.Rule(service['good'] | qua1ity['good'], tip['high'])

rule1.view()
```

```
(‹Figure size 640x480 with I Axes>, ‹Axes: >)
```

```
tippin          ctrl          =
ctrl.ControlSystem([rulel,
rule2, rule3])
```

```
print(tippi
ng.output['
```