

<b>Practical No</b>	<b>Details</b>	<b>Date</b>	<b>Sign</b>
<b>1</b>	Implement the following:		
<b>a</b>	Design a simple linear neural network model.		
<b>b</b>	Calculate the output of neural net using both binary and bipolar sigmoidal function.		
<b>2</b>	Implement the following:		
<b>a</b>	Generate AND/NOT function using McCulloch-Pitts neural net.		
<b>b</b>	Generate XOR function using McCulloch-Pitts neural net.		
<b>3</b>	Implement the Following		
<b>a</b>	Write a program to implement Hebb's rule.		
<b>b</b>	Write a program to implement of delta rule.		
<b>4</b>	Implement the Following		
<b>a</b>	Write a program for Back Propagation Algorithm		
<b>b</b>	Write a program for error Backpropagation algorithm.		
<b>5.</b>	Implement the Following		
<b>a</b>	Write a program for Hopfield Network.		
<b>b</b>	Write a program for Radial Basis function		
<b>6.</b>	Implement the Following		
<b>a</b>	Kohonen Self organizing map		
<b>b</b>	Adaptive resonance theory		
<b>7.</b>	Implement the Following		
<b>a</b>	Write a program for Linear separation.		
<b>b</b>	Write a program for Hopfield network model for associative memory		
<b>8.</b>	Implement the Following		

<b>a</b>	Membership and Identity Operators   in, not in,		
<b>b.</b>	Membership and Identity Operators is, is not		
<b>9.</b>	Implement the Following		
<b>a</b>	Find ratios using fuzzy logic		
<b>b</b>	Solve Tipping problem using fuzzy logic		
<b>10.</b>	Implement the Following		
<b>a</b>	Implementation of Simple genetic algorithm		
<b>b</b>	Create two classes: City and Fitness using Genetic algorithm		

## Practical 1a

**Aim: Design a simple linear neural network model.**

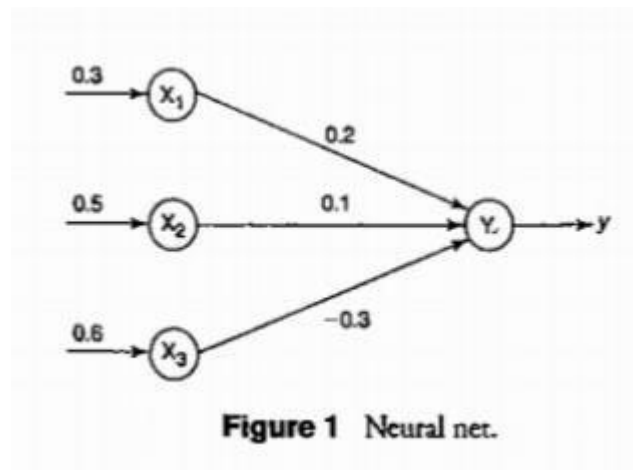
```
x=float(input("Enter value of x:"))  
w=float(input("Enter value of weight w:"))  
b=float(input("Enter value of bias b:"))
```

```
net = int(w*x+b)  
if(net<0): out=0  
elif((net>=0)&(net<=1)):  
    out =net  
else:  
    out=1  
print("net=",net)  
print("output=",out)
```

## Practical 1b

**Aim: Calculate the output of neural net using both binary and bipolar sigmoidal function.**

For the network shown in the figure 1, calculate the net input to output neuron.



**Solution :** The given neural net consist of three input neurons and one output neuron.

The inputs and weight are

$$[x_1, x_2, x_3] = [0.3, 0.5, 0.6]$$

$$[w_1, w_2, w_3] = [0.2, 0.1, -0.3]$$

The net input can be calculated as

$$\begin{aligned} Y_{in} &= x_1w_1 + x_2w_2 + x_3w_3 \\ &= 0.3*0.2 + 0.5*0.1 + 0.6*(-0.3) \\ &= -0.07 \end{aligned}$$

**Code :**

```
# number of elements as input
n = int(input("Enter number of elements : "))

# In[2]: print("Enter the inputs") inputs = [] #
creating an empty list for inputs

# iterating till the range for
i in range(0, n):
    ele = float(input()) inputs.append(ele) # adding
the element

print(inputs)

# In[3]: print("Enter the weights") #
creating an empty list for weights weights
= []

# iterating till the range for
i in range(0, n):
    ele = float(input()) weights.append(ele) # adding
the element

print(weights)

# In[4]:
print("The net input can be calculated as  $Y_{in} = x_1w_1 + x_2w_2 + x_3w_3$ ")

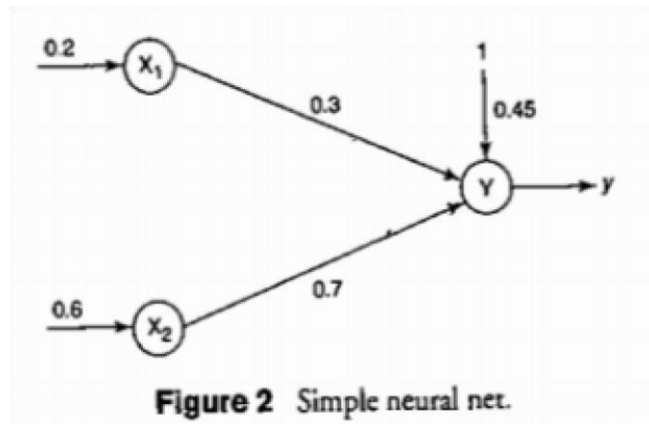
# In[5]: Yin = [] for
i in range(0, n):
    Yin.append(inputs[i]*weights[i]) print(round(sum(Yin),3))
```

**Output :**

```
Enter number of elements : 3
Enter the inputs
0.3
0.5
0.6
[0.3, 0.5, 0.6]
Enter the weights
0.2
0.1
-0.3
[0.2, 0.1, -0.3]
The net input can be calculated as  $Y_{in} = x_1w_1 + x_2w_2 + x_3w_3$ 
-0.07
```

### 1. Problem statement :

1. Calculate the net input for the network shown in Figure 2 with bias included in the network.



**Solution:** The given net consists of two input neurons, a bias and an output neuron. The inputs are

$[x_1, x_2] = [0.2, 0.6]$  and the weights are  $[w_1, w_2] = [0.3, 0.7]$ . Since the bias is included  $b = 0.45$  and bias input  $x_0$  is equal to 1, the net input is calculated as

$$\begin{aligned} Y_{in} &= b + x_1 W_1 + x_2 W_2 \\ &= 0.45 + 0.2 \times 0.3 + 0.6 \times 0.7 \\ &= 0.45 + 0.06 + 0.42 = 0.93 \end{aligned}$$

$y_m = 0.93$  is the net input.

**Code :** `n = int(input("Enter number of elements : "))`

```
print("Enter the inputs:")
inputs = [] # creating an empty list for inputs
for i in range(0, n):
    ele = float(input())    inputs.append(ele) # adding
the element print(inputs)
```

```
print("Enter the weights:")
weights = []    for i in
range(0, n):
    ele = float(input())    weights.append(ele) # adding
the element print(weights)
```

```
b=float(input("Enter bias value:")) print("The net input can be  
calculated as  $Y_{in} = b + x_1w_1 + x_2w_2$ :")
```

```
Yin = [] for i in range(0,  
n):
```

```
    Yin.append(inputs[i]*weights[i]) print(round((sum(Yin)+b),3))
```

```
Enter number of elements : 2
```

```
Enter the inputs:
```

```
0.2
```

```
0.6
```

```
[0.2, 0.6]
```

```
Enter the weights:
```

```
0.3
```

```
0.7
```

```
[0.3, 0.7]
```

```
Enter bias value:0.45
```

```
The net input can be calculated as  $Y_{in} = b + x_1w_1 + x_2w_2$ :  
0.93
```

## Practical 2a:

**Aim: Implement AND/NOT function using McCulloch-Pits neuron (use binary data representation).**

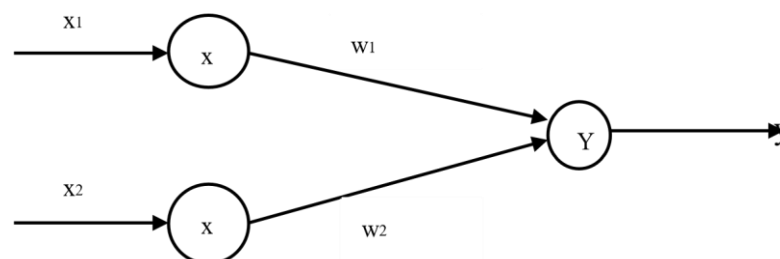
### Solution:

In the case of AND/NOT function, the response is true if the first input is true and the second input is false. For all the other variations, the response is false. The truth table for ANDNOT function is given in Table below.

### Truth Table:

x <sub>1</sub>	x <sub>2</sub>	y
0	0	0
0	1	0
1	0	1
1	1	0

The given function gives an output only when  $x_1 = 1$  and  $x_2 = 0$ . The weights have to be decided only after the analysis. The net can be represent as shown in figure below:



Neural net (weights fixed after analysis).

Case 1: Assume that both weights  $w_1$  and  $w_2$ . are excitatory, i.e.,

$$w_1 = w_2 = 1$$

Then for the four inputs calculate the net input using

$$y_{ij} = x_1 w_1 + x_2 w_2$$

For inputs

$$(1, 1), y_{ij} = 1 \times 1 + 1 \times 1 = 2$$

$$(1, 0), y_{ij} = 1 \times 1 + 0 \times 1 = 1 \quad (0,$$

$$1), y_{ij} = 0 \times 1 + 1 \times 1 = 1 \quad (0, 0),$$

$$y_{ij} = 0 \times 1 + 0 \times 1 = 0$$

From the calculated net inputs, it is not possible to fire the neuron from input (1, 0) only. Hence, J-. weights are not suitable.

Assume one weight as excitatory and the other as inhibitory, i.e.,

$$w_1 = 1, w_2 = -1$$

Now calculate the net input. For the inputs

$$(1,1), y_{in} = 1 \times 1 + 1 \times -1 = 0$$

$$(1,0), y_{in} = 1 \times 1 + 0 \times -1 = 1$$

$$(0,1), y_{in} = 0 \times 1 + 1 \times -1 = -1$$

$$(0, 0), y_{in} = 0 \times 1 + 0 \times -1 = 0$$

From the calculated net inputs, now it is possible to fire the neuron for input (1, 0) only by fixing a threshold of 1, i.e.,  $\theta \geq 1$  for Y unit. Thus,

$$w_1 = 1, w_2 = -1; \theta \geq 1$$

Note: The value is calculated using the following:  $\theta$

$$\geq nw - p$$

$$\theta \geq 2 \times 1 - 1 \quad \theta$$

$$\geq 1$$

Thus, the output of neuron Y can be written as

$$y = f(y_{in}) = \begin{cases} 0 & \text{if } y_{in} \geq 1 \\ 1 & \text{if } y_{in} < 1 \end{cases}$$



Code:

```
# enter the no of inputs num_ip = int(input("Enter the  
number of inputs : "))
```

```
#Set the weights with value 1 w1  
= 1 w2 = 1
```

```
print("For the ", num_ip , " inputs calculate the net input using  $y_{in} = x_1w_1 + x_2w_2$  ")
```

```
x1 = [] x2 = [] for j in  
range(0, num_ip): ele1 =  
int(input("x1 = ")) ele2 =  
int(input("x2 = "))  
x1.append(ele1) x2.append(ele2)  
print("x1 =  
",x1) print("x2 = ",x2)
```

```
n = x1 * w1 m =  
x2 * w2
```

```
Yin = [] for i in range(0, num_ip):  
Yin.append(n[i] + m[i]) print("Yin =  
",Yin)
```

#Assume one weight as excitatory and the other as inhibitory, i.e.,

```
Yin = [] for i in range(0, num_ip):  
Yin.append(n[i] - m[i])  
print("After assuming one weight as excitatory and the other as inhibitory Yin = ",Yin)
```

#From the calculated net inputs, now it is possible to fire the neuron for input (1, 0) #only by fixing a threshold of 1, i.e.,  $\theta \geq 1$  for Y unit.

#Thus,  $w_1 = 1$ ,  $w_2 = -1$ ;  $\theta \geq 1$

```
Y=[]
```

```
for i in range(0, num_ip):  
if(Yin[i]>=1):  
ele= 1  
Y.append(ele) if(Yin[i]<1):  
ele= 0
```

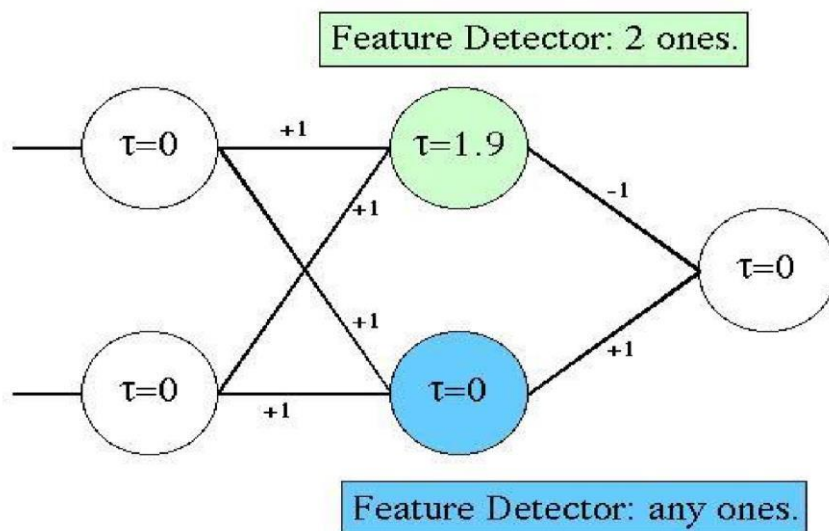
```
Y.append(ele) print("Y =  
",Y) Output:
```

```
Enter the number of inputs : 4  
For the 4 inputs calculate the net input using  $y_{in} = x_1w_1 + x_2w_2$   
  
x1 = 0  
x2 = 0  
  
x1 = 0  
x2 = 1  
  
x1 = 1  
x2 = 0  
  
x1 = 1  
x2 = 1  
x1 = [0, 0, 1, 1]  
x2 = [0, 1, 0, 1]  
Yin = [0, 1, 1, 2]  
After assuming one weight as excitatory and the other as inhibitory Yin = [0, 1, -1, 0]  
Y = [0, 1, 0, 0]  
  
In [14]: |
```

### Practical 2b:

**Aim: Generate XOR function using McCulloch-Pitts neural net**

## XOR Network



The XOR (exclusive or) function is defined by the following truth table:

**Input1 Input2 XOR Output**

0	0	0
0	1	1
1	0	1
1	1	0

#Getting weights and threshold value

```
import numpy as np
print('Enter weights')
w11=int(input('Weight w11='))
w12=int(input('weight w12='))
w21=int(input('Weight w21='))
w22=int(input('weight w22='))
v1=int(input('weight v1='))
v2=int(input('weight v2='))
print('Enter Threshold Value')
theta=int(input('theta='))
x1=np.array([0, 0, 1, 1])
x2=np.array([0, 1, 0, 1])
z=np.array([0, 1, 1, 0])
con=1
y1=np.zeros((4,))
y2=np.zeros((4,))
y=np.zeros((4,))
while con==1:
    zin1=np.zeros((4,))
    zin2=np.zeros((4,))
    zin1=x1*w11+x2*w21
    zin2=x1*w21+x2*w22

    print("z1",zin1)
    print("z2",zin2)
    for i in range(0,4):
        if
```

```

zin1[i]>=theta:      y1[i]=1
else:      y1[i]=0
if zin2[i]>=theta:

    y2[i]=1
else:      y2[i]=0
yin=np.array([])
yin=y1*v1+y2*v2    for
i in range(0,4):    if
yin[i]>=theta:

    y[i]=1    else:
    y[i]=0

print("yin",yin)
print('Output of Net')
y=y.astype(int)
print("y",y)    print("z",z)

if np.array_equal(y,z):
    con=0
else:

    print("Net is not learning enter another set of weights and Threshold value")
w11=input("Weight w11=")    w12=input("weight w12=")
w21=input("Weight w21=")    w22=input("weight w22=")    v1=input("weight
v1=")    v2=input("weight v2=")    theta=input("theta=")

print("McCulloch-Pitts Net for XOR function")
print("Weights of Neuron Z1") print(w11)
print(w21) print("weights of Neuron Z2") print(w12)

```

```

print(w22) print("weights of
Neuron Y") print(v1) print(v2)
print("Threshold value")
print(theta)

```

```

Enter weights
Weight w11=1
weight w12=-1
Weight w21=-1
weight w22=1
weight v1=1
weight v2=1
Enter Threshold Value
theta=1
z1 [ 0 -1  1  0]
z2 [ 0  1 -1  0]
yin [0. 1. 1. 0.]
Output of Net
y [0 1 1 0]
z [0 1 1 0]
McCulloch-Pitts Net for XOR function
Weights of Neuron Z1
1
-1
weights of Neuron Z2
-1
1
weights of Neuron Y
1
1
Threshold value
1

```

### **Practical 3a.**

**Aim: Write a program to implement Hebb's rule.**

The Hebbian Learning Rule is a learning rule that specifies how much the weight of the connection between two units should be increased or decreased in proportion to the product of their activation. The rule builds on Hebb's 1949 learning rule which states that the connections between two neurons might be strengthened if the neurons fire simultaneously. The Hebbian Rule works well as long as all the input patterns are orthogonal or uncorrelated. The requirement of orthogonality places serious limitations on the Hebbian Learning Rule. A more powerful learning rule is the delta rule, which utilizes the discrepancy between the desired and actual output of each output unit to change the weights feeding into it.

**Hebb's rule with an analogy. Psychology and neuroscience**

**The Hebb's principle or Hebb's rule**

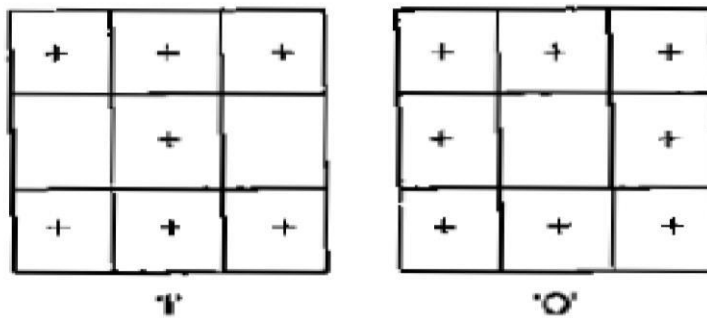
Hebb says that "when the axon of a cell A is close enough to excite a B cell and takes part on its activation in a repetitive and persistent way, some type of growth process or metabolic change takes place in one or both cells, so that increases the efficiency of cell A in the activation of B".

*'neurons that fire together wire together'*

It is customary to be summarized as "neurons that fire together wire together". That is, the simultaneous activation of nearby neurons leads to an increase in the strength of synaptic connection between them.

It is important to note that the neurons must be previously connected, sufficiently close to one another, so that the synapse can be reinforced. Hebb's principle can be described as a method of determining how to alter the weights between model neurons. The weight between two neurons increases if the two neurons activate simultaneously, and reduces if they activate separately. Nodes that tend to be either both positive or both negative at the same time have strong positive weights, while those that tend to be opposite have strong negative weights.

Using the Hebb rule, find the weights required to perform the following classifications of the given input patterns shown in Figure 16. The pattern is shown as  $3 \times 3$  matrix form in the squares. The “+” symbols represent the value “1” and empty squares indicate “-1.” Consider “I” belongs to the members of class (so has target value 1) and “O” does not belong to the members of class (so has target value -1).



```
import numpy as np
#first pattern
x1=np.array([1,1,1,-1,1,-1,1,1,1])
#second pattern
x2=np.array([1,1,1,1,-1,1,1,1,1])
#initialize bias value b=0
#define target
y=np.array([1,-1])

wtold=np.zeros((9,))
wtnew=np.zeros((9,))

wtnew=wtnew.astype(int)
wtold=wtold.astype(int)

bais=0
print("First input with target =1")
for i in range(0,9):
    wtold[i]=wtold[i]+x1[i]*y[0]
    wtnew=wtold
    b=b+y[0]
print("new wt =", wtnew)
print("Bias value",b)

print("Second input with target =-1")
```

```

for i in range(0,9):
wtnew[i]=wtold[i]+x2[i]*y[1]
b=b+y[1] print("new wt
=", wtnew) print("Bias
value",b)

```

```

First input with target =1
new wt = [ 1  1  1 -1  1 -1  1  1  1]
Bias value 1
Second input with target =-1
new wt = [ 0  0  0 -2  2 -2  0  0  0]
Bias value 0

```

### Practical 3b:

**Aim: Write a program to implement of delta rule.**

```

#supervised learning import numpy
as np import time
np.set_printoptions(precision=2)
x=np.zeros((3,))
weights=np.zeros((3,))
desired=np.zeros((3,))
actual=np.zeros((3,))

for i in range(0,3):

    x[i]=float(input("Initial inputs:")) for i in
range(0,3):  weights[i]=float(input("Initial weights:"))

for i in range(0,3):
    desired[i]=float(input("Desired output:")) a=float(input("Enter
learning rate:"))

```



```

actual=x*weights print("actual",actual) print("desired",desired)
while True: if np.array_equal(desired,actual):
break #no change else: for i in range(0,3):
weights[i]=weights[i]+a*(desired[i]-actual[i])
actual=x*weights print("weights",weights)
print("actual",actual) print("desired",desired) print("***30)
print("Final output") print("Corrected weights",weights)
print("actual",actual) print("desired",desired)

```

```

Initial inputs:1
Initial inputs:1
Initial inputs:1
Initial weights:1
Initial weights:1
Initial weights:1
Desired output:2
Desired output:3
Desired output:4
Enter learning rate:1
actual [1. 1. 1.]
desired [2. 3. 4.]
weights [2. 3. 4.]
actual [2. 3. 4.]
desired [2. 3. 4.]
*****
Final output
corrected weights [2. 3. 4.]
actual [2. 3. 4.]
desired [2. 3. 4.]

```

## Practical 4a:

**Aim: Write a program for Back Propagation Algorithm**

### Back-propagation

want:  $y^*$

1. receive new observation  $\mathbf{x} = [x_1 \dots x_d]$  and target  $y^*$
2. **feed forward:** for each unit  $g_j$  in each layer  $1 \dots L$   
compute  $g_j$  based on units  $f_k$  from previous layer:  $g_j = \sigma \left( u_{j0} + \sum_k u_{jk} f_k \right)$
3. get prediction  $y$  and error  $(y - y^*)$
4. **back-propagate error:** for each unit  $g_j$  in each layer  $L \dots 1$

(a) compute error on  $g_j$

$$\frac{\partial E}{\partial g_j} = \sum_i \underbrace{\sigma'(h_i)}_{\text{how } h_i \text{ will change as } g_j \text{ changes}} \underbrace{v_{ij}}_{\text{was } h_i \text{ too high or too low?}} \frac{\partial E}{\partial h_i}$$

should  $g_j$  be higher or lower?

(b) for each  $u_{jk}$  that affects  $g_j$

(i) compute error on  $u_{jk}$

$$\frac{\partial E}{\partial u_{jk}} = \frac{\partial E}{\partial g_j} \underbrace{\sigma'(g_j)}_{\text{do we want } g_j \text{ to be higher/lower}} \underbrace{f_k}_{\text{how } g_j \text{ will change if } u_{jk} \text{ is higher/lower}}$$

(ii) update the weight

$$u_{jk} \leftarrow u_{jk} - \eta \frac{\partial E}{\partial u_{jk}}$$

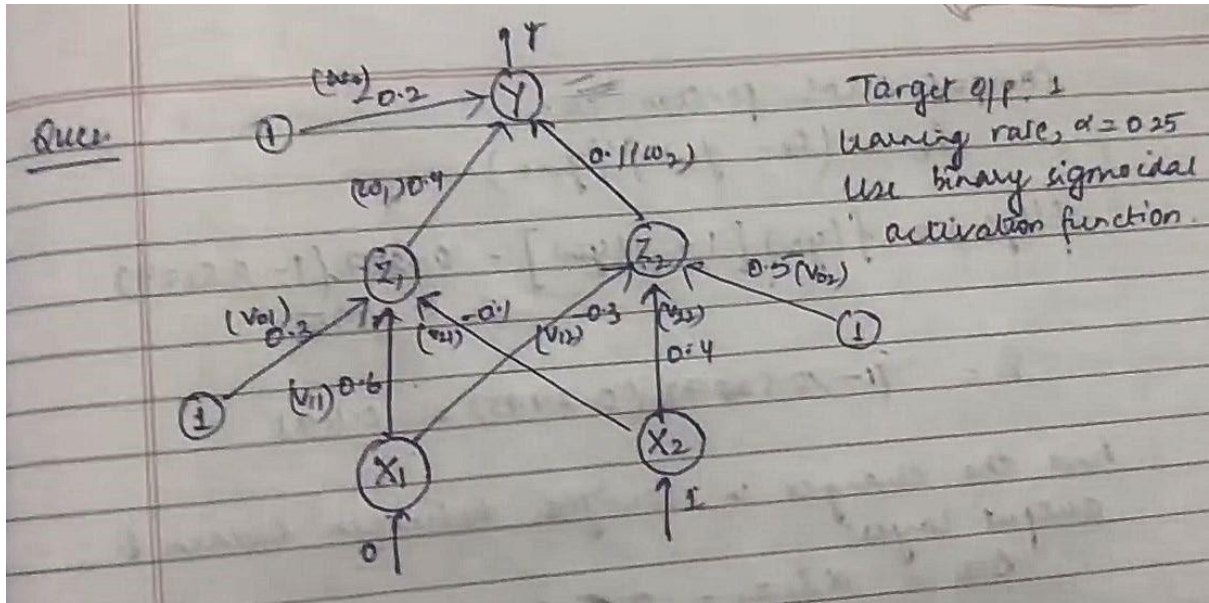
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### Backpropagating $dE/dy$

$$\frac{\partial E}{\partial z_j} = \frac{dy_j}{dz_j} \frac{\partial E}{\partial y_j} = y_j (1 - y_j) \frac{\partial E}{\partial y_j}$$

$$\frac{\partial E}{\partial y_i} = \sum_j \frac{dz_j}{dy_i} \frac{\partial E}{\partial z_j} = \sum_j w_{ij} \frac{\partial E}{\partial z_j}$$

$$\frac{\partial E}{\partial w_{ij}} = \frac{\partial z_j}{\partial w_{ij}} \frac{\partial E}{\partial z_j} = y_i \frac{\partial E}{\partial z_j}$$



```

import numpy as np
import decimal
import math

np.set_printoptions(precision=2)
v1=np.array([0.6, 0.3])
v2=np.array([0.1, 0.4])
w=np.array([-0.2,0.4,0.1])
b1=0.3
b2=0.5
x1=0
x2=1
alpha=0.25

print("calculate net input to z1 layer")
zin1=round(b1+ x1*v1[0]+x2*v2[0],4)
print("z1=",round(zin1,3))

print("calculate net input to z2 layer")
zin2=round(b2+ x1*v1[1]+x2*v2[1],4)
print("z2=",round(zin2,4))
print("Apply activation function to calculate output")
z1=1/(1+math.exp(-zin1))
z1=round(z1,4)
z2=1/(1+math.exp(-zin2))
z2=round(z2,4)
print("z1=",z1)
print("z2=",z2)

print("calculate net input to output layer")
yin=w[0]+z1*w[1]+z2*w[2]

```

```
print("yin=",yin)
```

```
print("calculate net output")
```

```
y=1/(1+math.exp(-yin)) print("y=",y)
```

```
fyin=y *(1- y) dk=(1-  
y)*fyin print("dk",dk)
```

```
dw1= alpha * dk * z1 dw2=  
alpha * dk * z2 dw0= alpha  
* dk
```

```
print("compute error portion in delta")
```

```
din1=dk* w[1] din2=dk*  
w[2] print("din1=",din1)  
print("din2=",din2)  
print("error in delta")  
fzin1= z1 *(1-z1)  
print("fzin1",fzin1)  
d1=din1* fzin1 fzin2= z2  
*(1-z2)  
print("fzin2",fzin2)  
d2=din2* fzin2
```

```
print("d1=",d1) print("d2=",d2) print("Changes in weights between input and hidden layer")  
dv11=alpha * d1 * x1 print("dv11=",dv11) dv21=alpha * d1
```

```

* x2 print("dv21=",dv21) dv01=alpha * d1 print("dv01=",dv01) dv12=alpha *
d2 * x1 print("dv12=",dv12) dv22=alpha * d2 * x2 print("dv22=",dv22)
dv02=alpha * d2 print("dv02=",dv02)

```

```

print("Final weights of network")

```

```

v1[0]=v1[0]+dv11

```

```

v1[1]=v1[1]+dv12 print("v=",v1)

```

```

v2[0]=v2[0]+dv21

```

```

v2[1]=v2[1]+dv22 print("v2",v2)

```

```

w[1]=w[1]+dw1

```

```

w[2]=w[2]+dw2

```

```

b1=b1+dv01

```

```

b2=b2+dv02

```

```

w[0]=w[0]+dw0

```

```

print("w=",w) print("bias

```

```

b1=",b1, " b2=",b2)

```

```

z1= 0.2
calculate net input to z2 layer
z2= 0.9
Apply activation function to calculate output
z1= 0.5498
z2= 0.7109
calculate net input to output layer
yin= 0.09101
calculate net output
y= 0.5227368084248941
dk 0.11906907074145694
compute error portion in delta
din1= 0.04762762829658278
din2= 0.011906907074145694
error in delta
fzin1 0.24751996
fzin2 0.20552119000000002
d1= 0.011788788650865037
d2= 0.0024471217110978417
Changes in weights between input and hidden layer
dv11= 0.0
dv21= 0.0029471971627162592
dv01= 0.0029471971627162592
dv12= 0.0
dv22= 0.0006117804277744604
dv02= 0.0006117804277744604
Final weights of network
v= [0.6 0.3]
v2 [-0.1 0.4]
w= [-0.17 0.42 0.12]
bias b1= 0.30294719716271623 b2= 0.5006117804277744

```

## Practical 4b

**Aim: Write a Program For Error Back Propagation Algorithm (Ebpa) Learning**

```
import math a0=-1 t=-1 w10=float(input("Enter
weight first network")) b10=float(input("Enter base
first network:")) w20=float(input("Enter weight
second network:")) b20=float(input("Enter base
second network:"))
c=float(input("Enter learning coefficient:"))
n1=float(w10*c+b10)
a1=math.tanh(n1)
n2=float(w20*a1+b20)
a2=math.tanh(float(n2))
e=t-a2 s2=-2*(1-a2*a2)*e
s1=(1-a1*a1)*w20*s2

w21=w20-(c*s2*a1) w11=w10-(c*s1*a0)
b21=b20-(c*s2) b11=b10-(c*s1) print("The updated
weight of first n/w w11=",w11) print("The uploaded
weight of second n/w w21= ",w21) print("The updated
base of first n/w b10=",b10)
print("The updated base of second n/w b20= ",b20)
```

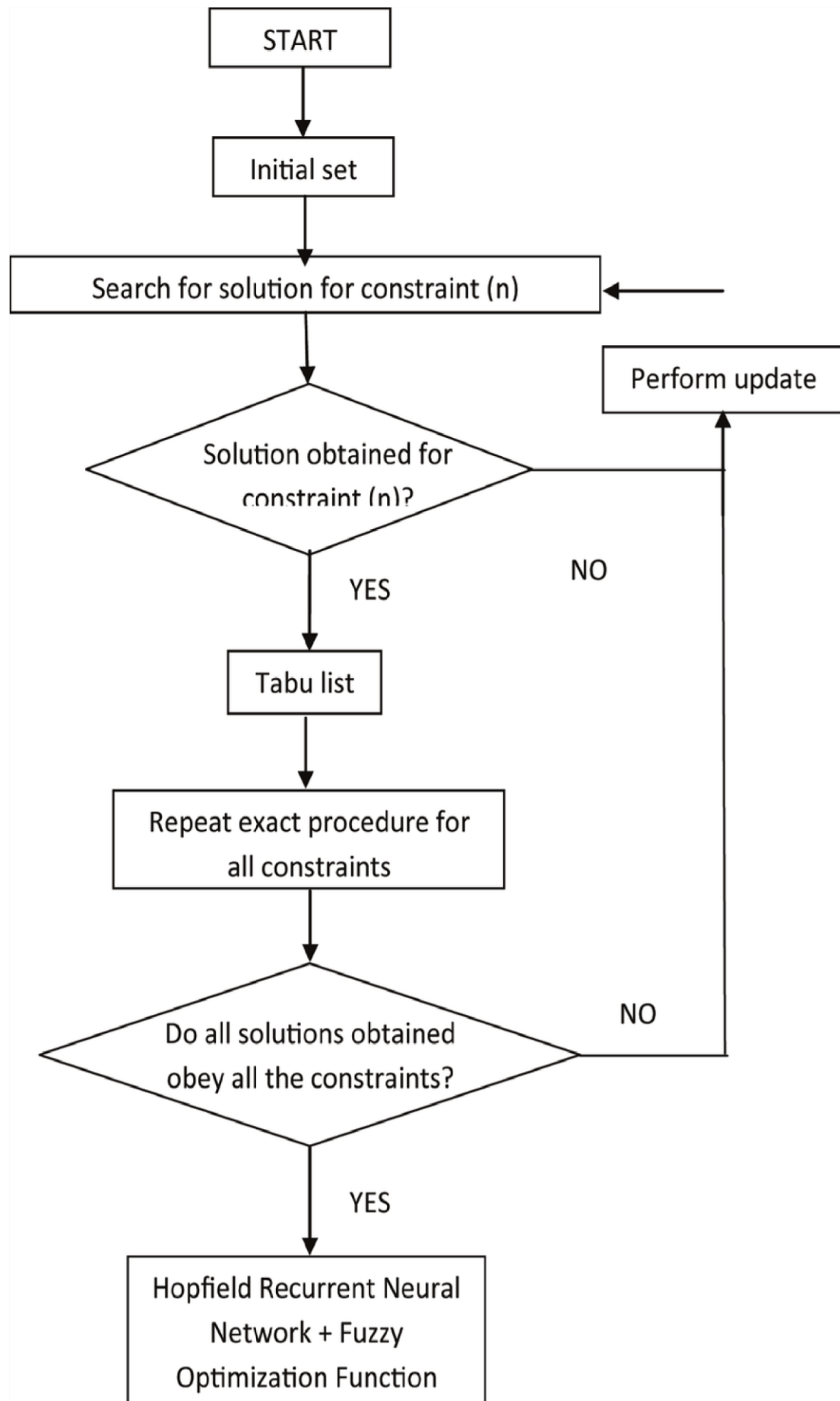
```
Enter weight first network:12
Enter base first network:35
Enter weight second network:23
Enter base second network:45
Enter learning coefficient:11
The updated weight of first n/w w11= 12.0
The uploaded weight of second n/w w21= 23.0
The updated base of first n/w b10= 35.0
The updated base of second n/w b20= 45.0
```

## Practical 5a:

Aim: Write a program for Hopfield Network.

### Algorithm

- Step 0.** Initialize activations of all units.  
Initialize  $\Delta t$  to a small value.
- Step 1.** While the stopping condition is false, do Steps 2–6.
- Step 2.** Perform Steps 3–5  $n^2$  times ( $n$  is the number of cities).
- Step 3.** Choose a unit at random.
- Step 4.** Change activity on selected unit:
- $$u_{x,i}(\text{new}) = u_{x,i}(\text{old}) + \Delta t \left[ -u_{x,i}(\text{old}) - A \sum_{j \neq i} v_{x,j} - B \sum_{y \neq x} v_{y,i} + C \left\{ N - \sum_x \sum_j v_{x,j} \right\} - D \sum_{y \neq x} d_{x,y} (v_{y,i+1} + v_{y,i-1}) \right].$$
- Step 5.** Apply output function:
- $$v_{x,i} = 0.5[1 + \tanh(\alpha u_{x,i})].$$
- Step 6.** Check stopping condition.





```

#include "hop.h" neuron::neuron(int *j)
{
inti;
for(i=0;i<4;i++)
{
weightv[i]= *(j+i);
} }
int neuron::act(int m, int *x)
{ inti; int a=0; for(i=0;i<m;i++)
{
a += x[i]*weightv[i];
}
return a; }
int network::threshld(int k)
{ if(k>=0) return (1); else
return (0); }
network::network(int a[4],int b[4],int c[4],int d[4])
{ nrn[0] = neuron(a)
; nrn[1] = neuron(b) ; nrn[2] = neuron(c)
; nrn[3] = neuron(d)
;
}

void network::activation(int *patrn)
{
inti,j;
for(i=0;i<4;i++)
{
for(j=0;j<4;j++)
{
cout<<"\n nrn["<<i<<"].weightv["<<j<<"] is "
<<nrn[i].weightv[j];
}
nrn[i].activation = nrn[i].act(4,patrn);
cout<<"\nactivation is "<<nrn[i].activation; output[i]=threshld(nrn[i].activation);
cout<<"\noutput value is "<<output[i]<<"\n";
} } void main () { int patrn1[]=
{1,0,1,0},i; int wt1[]=
{0,-3,3,-3}; int wt2[]= {-
3,0,-3,3}; int wt3[]= {3,-
3,0,-3}; int wt4[]= {-
3,3,-3,0};

```

```

cout<<"\nTHIS PROGRAM IS FOR A HOPFIELD NETWORK WITH A SINGLE LAYER
OF";
cout<<"\n4 FULLY INTERCONNECTED NEURONS. THE NETWORK SHOULD RECALL THE";
cout<<"\nPATTERNS 1010 AND 0101 CORRECTLY.\n";
//create the network by calling its constructor.
// the constructor calls neuron constructor as many times as thenumber of // neurons in the network.
network h1(wt1,wt2,wt3,wt4);
//present a pattern to the network and get the activations of the neurons h1.activation(patrn1);
//check if the pattern given is correctly recalled and give message for(i=0;i<4;i++)
{
    if (h1.output[i] == patrn1[i])        cout<<"\n pattern=
"<<patrn1[i]<<
        " output = "<<h1.output[i]<<" component matches";    else
        cout<<"\n pattern= "<<patrn1[i]<<
        " output = "<<h1.output[i]<<
        " discrepancy occurred";
}
cout<<"\n\n"; int
patrn2[] = {0,1,0,1}; h1.activation(patrn2);
for(i=0;i<4;i++)
{
    if (h1.output[i] == patrn2[i])        cout<<"\n pattern=
"<<patrn2[i]<<        " output = "<<h1.output[i]<<" component
matches";    else
        cout<<"\n pattern= "<<patrn2[i]<<
        " output = "<<h1.output[i]<<
        " discrepancy occurred";
}
}
===== End code of main program=====
//Hop.h
//Single layer Hopfield Network with 4 neurons
#include <stdio.h>
#include <iostream.h> #include <math.h>    class    neuron
{
protected:    int activation;    friend class network; public:
intweightv[4];    neuron() {};    neuron(int *j);    int
act(int, int*); }; class network { public:    neuron    nrn[4];
int output[4];    intthreshld(int);    void activation(int
j[4]);
network(int*,int*,int*,int*);
};

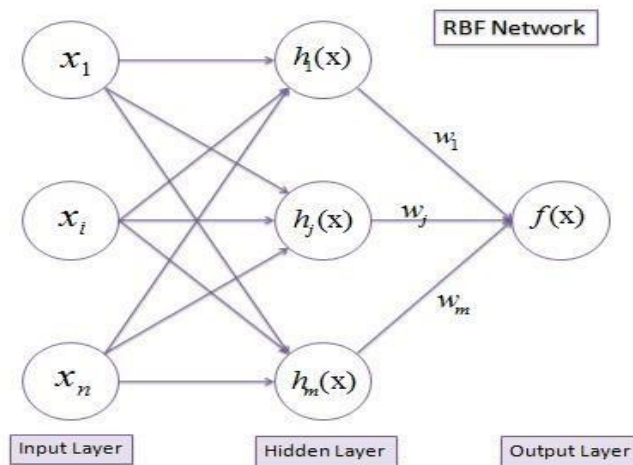
```

## Practical 5b:

**Aim:** Write a program for Radial Basis function

### Radial Basis Function Networks (RBF)

RBF networks have three layers: input layer, hidden layer and output layer. One neuron in the input layer corresponds to each predictor variable. With respects to categorical variables,  $n-1$  neurons are used where  $n$  is the number of categories. Hidden layer has a variable number of neurons. Each neuron consists of a radial basis function centered on a point with the same dimensions as the predictor variables. The output layer has a weighted sum of outputs from the hidden layer to form the network outputs.



$$f(x) = \sum_{j=1}^m w_j h_j(x)$$

$$h(x) = \exp\left(-\frac{(x-c)^2}{r^2}\right)$$

### Algorithm

$h(x)$  is the Gaussian activation function with the parameters  $r$  (the radius or standard deviation) and  $c$  (the center or average taken from the input space) defined separately at each RBF unit. The learning process is based on adjusting the parameters of the network to reproduce a set of input-output patterns. There are three types of parameters; the weight  $w$  between the hidden nodes and the output nodes, the center  $c$  of each neuron of the hidden layer and the unit width  $r$ .

### Unit Center ( $c$ )

Any clustering algorithm can be used to determine the RBF unit centers (e.g., K-means clustering). A set of clusters each with  $r$ -dimensional centers is determined by the number of input variables or nodes of the input layer. The cluster centers become the centers of the RBF units. The number of clusters,  $H$ , is a design parameter and determines the number of nodes in the hidden layer. The K-means clustering algorithm proceeds as follows:

1. Initialize the center of each cluster to a different randomly selected training pattern. 5
2. Assign each training pattern to the nearest cluster. This can be accomplished by calculating the Euclidean distances between the training patterns and the cluster centers.
3. When all training patterns are assigned, calculate the average position for each cluster center. They then become new cluster centers.
4. Repeat steps 2 and 3, until the cluster centers do not change during the subsequent iterations.

### Unit width ( $r$ )

When the RBF centers have been established, the width of each RBF unit can be calculated using the Knearest neighbors algorithm. A number  $K$  is chosen, and for each center, the  $K$  nearest centers is found. The root-mean squared distance between the current cluster center and its  $K$  nearest neighbors is calculated, and this is the value chosen for the unit width ( $r$ ). So, if the current cluster center is  $c_j$ , the  $r$  value is:

$$r_j = \sqrt{\frac{\sum_{i=1}^k (c_j - c_i)^2}{k}}$$

A typical value for  $K$  is 2, in which case  $s$  is set to be the average distance from the two nearest neighboring cluster centers.

### Weights ( $w$ )

Using the linear mapping,  $w$  vector is calculated using the output vector ( $y$ ) and the design matrix  $H$ .

$$y = wH$$

$$w = (H'H)^{-1} H'y$$

The basis functions are (unnormalized) gaussians, the output layer is linear and the weights are learned by a simple pseudo-inverse.

from scipy import \*

```

scipy.linalg import norm, pinv from matplotlib
import pyplot as plt

class RBF:

    def __init__(self, indim, numCenters, outdim):

self.indim =indim
self.outdim =outdim
self.numCenters =numCenters
self.centers =[random.uniform(-1, 1, indim) for i in range(numCenters)]
self.beta =8
self.W =random.random((self.numCenters, self.outdim))

    def _basisfunc(self, c, d):    assert

len(d)==self.indim    return exp(self.beta *norm(c-d)**2)

    def _calcAct(self, X):

        # calculate activations of RBFs

        G =zeros((X.shape[0], self.numCenters), float)
for ci, c in enumerate(self.centers):    for xi, x in
enumerate(X):    G[xi,ci] =self._basisfunc(c,
x)    return G

    def train(self, X, Y):

```

```

        """ X: matrix of dimensions n x indim
y: column vector of dimension n x 1 """      #
choose random center vectors from training set
rnd_idx
=random.permutation(X.shape[0]):self.numCe
nters]      self.centers =[X[i,:] for i in rnd_idx]

print("center", self.centers)

# calculate activations of RBFs      G
=self._calcAct(X)      print (G)

# calculate output weights (pseudoinverse)      self.W
=dot(pinv(G), Y)

def test(self, X):
    """ X: matrix of dimensions n x indim """

    G =self._calcAct(X)
    Y      =dot(G,      self.W)
    return Y

if __name__ == '__main__':
    # ----- 1D Example -----      n
    =100

    x =mgrid[-1:1:complex(0,n)].reshape(n, 1)
    # set y and add random noise      y

```

```

=sin(3*(x+0.5)**3-1)

# y += random.normal(0, 0.1, y.shape)

# rbf regression
rbf=RBF(1, 10, 1)
rbf.train(x, y)    z
=rbf.test(x)

# plot original data
plt.figure(figsize=(12, 8))
plt.plot(x, y, 'k-')

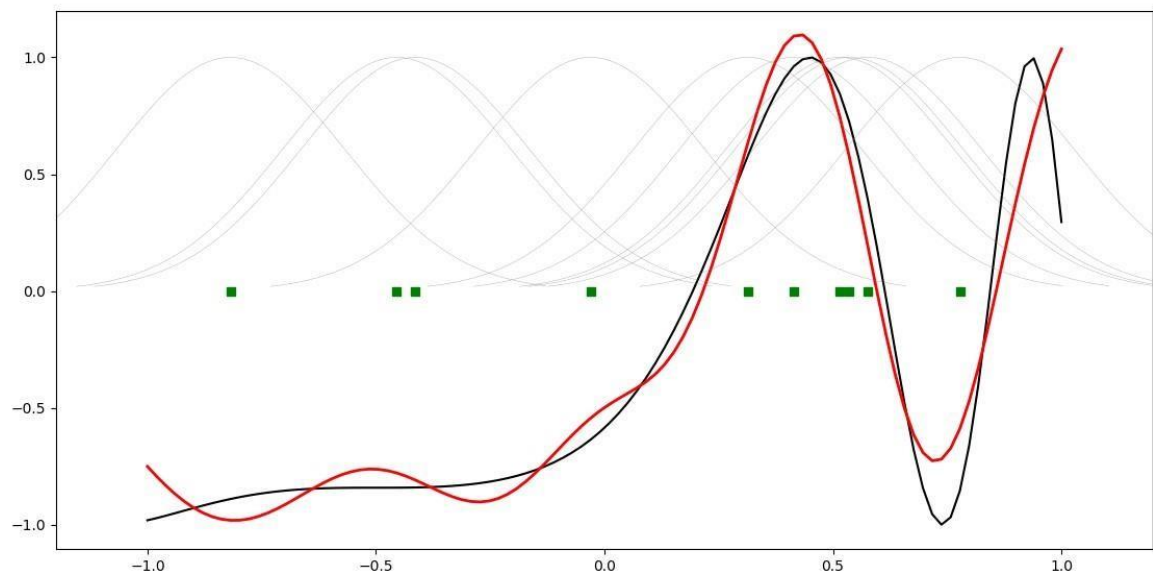
# plot learned model    plt.plot(x,
z, 'r-', linewidth=2)

# plot rbfs    plt.plot(rbf.centers,
zeros(rbf.numCenters), 'gs')

for c in rbf.centers:    # RF prediction lines    cx
=arange(c-0.7, c+0.7, 0.01)    cy
=[rbf._basisfunc(array([cx_]), array([c])) for cx_ in cx]    plt.plot(cx,
cy, '-', color='gray', linewidth=0.2)

plt.xlim(-1.2, 1.2)    plt.show()

```





## Practical 6a:

### Aim: Self-Organizing Maps

The SOM algorithm is used to compress the information to produce a similarity graph while preserving the topologic relationship of the input data space.

The basic SOM model construction algorithm can be interpreted as follows:

- 1) Create and initialize a matrix (weight vector) randomly to hold the neurons. If the matrix can be initialized with order and roughly compiles with the input density function, the map will converge quickly
- 2) Read the input data space. For each observation (instance), use the optimum fit approach, which is based on the Euclidean distance

$$c = \text{argmin}_{ii} \|x - m_{ii}\|$$

to find the neuron which best matches this observation. Let  $x$  denote the training vector from the observation and  $m_{ii}$  denote a single neuron in the matrix. Update that neuron to resemble that observation using the following equation:

$$m_{ii}(t+1) = m_{ii}(t) + h(t) \frac{x - m_{ii}(t)}{\|x - m_{ii}(t)\|} \quad (4)$$

weight vector before the neuron is updated.

$(t+1)$ : the weight vector after the neuron is updated.

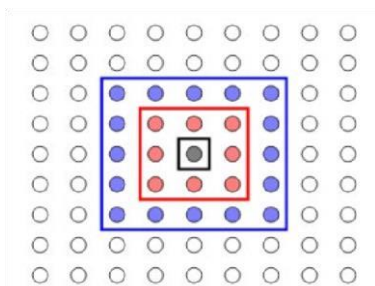
$(t)$ : the training vector from the observation.

$h(t)$ : the neighborhood function (a smoothing kernel defined over the lattice points), defined through the following equation:

$$h(t) = \begin{cases} \alpha(t) & \text{if } ii \in NNNN \\ 0 & \text{if } ii \notin NNNN \end{cases} \quad (5)$$

$\alpha(t)$ : the neighborhood set, which decreases with time.

$(t)$ : the learning-rate factor which can be linear, exponential or inversely proportional. It is a monotonically decreasing function of time ( $t$ )



In general, SOMs might be useful for visualizing high-dimensional data in terms of its similarity structure. Especially large SOMs (i.e. with large number of Kohonen units) are known to perform mappings that preserve the topology of the original data, i.e. neighboring data points in input space will also be represented in adjacent locations on the SOM. from minisom import MiniSom import matplotlib.pyplot as plt data = [[ 0.80, 0.55, 0.22, 0.03],

[ 0.82, 0.50, 0.23, 0.03], [

0.80, 0.54, 0.22, 0.03], [

0.80, 0.53, 0.26, 0.03], [

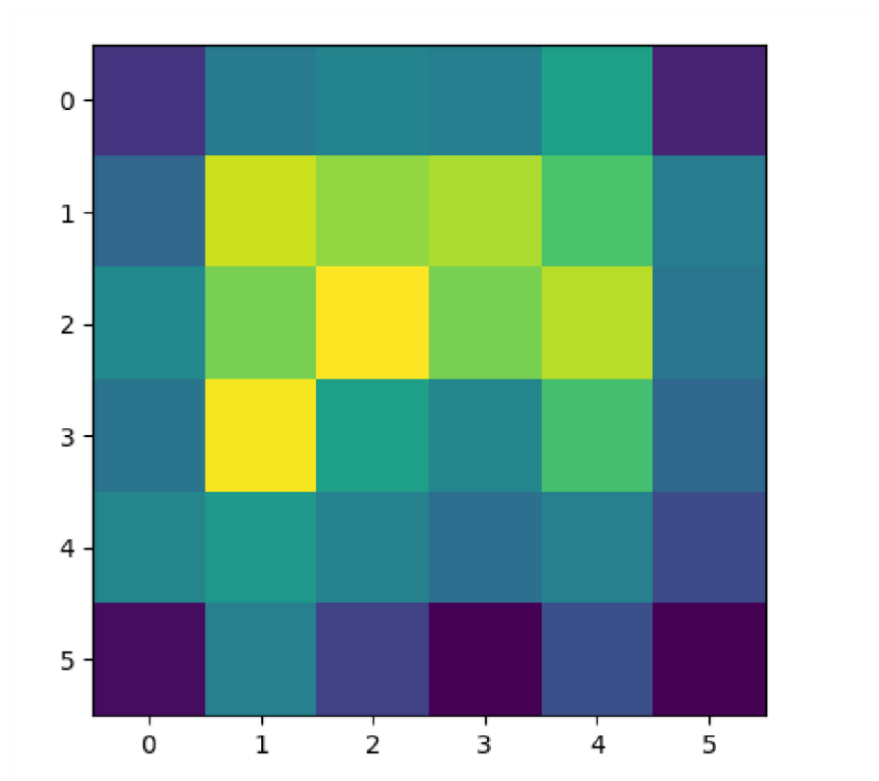
0.79, 0.56, 0.22, 0.03],

[ 0.75, 0.60, 0.25, 0.03], [ 0.77, 0.59, 0.22, 0.03]] som = MiniSom(6, 6, 4,

sigma=0.3, learning\_rate=0.5) # initialization of 6x6 SOM som.train\_random(data,

100) # trains the SOM with 100 iterations plt.imshow(som.distance\_map())

plt.show()



## Practical 6b:

### Aim: Adaptive resonance theory

#### ART Function: import

numpy as np

```
def initialForwardDirectionWeightFormula(N):  
    return (1) / (1 + N)
```

```
def initialForwardDirectionWeightMatrix(N,M):  
    return np.ones((N, M), dtype=np.uint8())
```

```
def previousBackwardWeight(forwardWeightMatrix):  
    return forwardWeightMatrix
```

```
def numberOfRowsAndColumns(matrix):  
    return matrix.shape[0], matrix.shape[1]
```

```
def calculateYList(N,inputList,forwardWeightList):  
    outputListY = [0,0,0]    for i in range(N):        for j in range(N):  
    outputListY[i] = outputListY[i] + (forwardWeightList[j] * inputList[j])    return  
    outputListY[0]
```

```
def maxYListInValue(YList):  
    return max(YList)
```

```
def fitnessTestS1(inputList):  
    s1 = 0    for i in  
inputList:  
        s1 = s1 + i  
    return s1
```

```
def fitnessTestS2(N,weightList,inputList,S1,p,YMax):  
    S2 = [0,0,0]    for i in range(N):        for j in  
range(N):  
        S2[i] = S2[i] + (weightList[j] * inputList[j])  
    s2 = S2[0] / S1  
    if(int(s2) >= p):  
        return updateForwardAndBackwardWeights(weightList,inputList,YMax)  
    else:  
        return 0
```

```

def updateForwardAndBackwardWeights(weightList,inputList,YMax):
    newBackwardWeight = [0,0,0]
    newForwardWeight = [0,0,0]

    for index in range(len(newBackwardWeight)):
        newBackwardWeight[index] = newBackwardWeight[index] + (weightList[index] *
inputList[index])

    seriesOperationList = [0,0,0]

    for i in range(len(newForwardWeight)):
for j in range(len(newForwardWeight)):
        seriesOperationList[i] = seriesOperationList[i] + (newBackwardWeight[i] * inputList[j])
newForwardWeight[i] = newForwardWeight[i] + ( (newBackwardWeight[i] * inputList[i]) / (YMax
+ (seriesOperationList[i]) ) ) )        return
newBackwardWeight,newForwardWeight Main:
import numpy as np
import ARTFunctions as art

# Magic Numbers -> %80 #
similarity_coefficient = 0.8

# M1, M2, M3 and P1,P2 and P3 values #
dataset = np.array([
    [1,0,1],
    [1,1,0],
    [0,0,1] ])

inputN,outputM = art.numberOfRowsAndColumns(dataset)

backwardWeight = art.initialForwardDirectionWeightMatrix(inputN,outputM)
forwardWeight = backwardWeight * art.initialForwardDirectionWeightFormula(inputN)

for i in range(inputN):
    YList = art.calculateYList(inputN,dataset[i],forwardWeight)
    maxYP = art.maxYListInValue(YList)
    PS1 = art.fitnessTestS1(dataset[i])
    newBackwardWeight, newForwardWeight = art.fitnessTestS2(inputN, backwardWeight[i], dataset[i],
PS1, similarity_coefficient, maxYP)    print("New Backward Weight : ", newBackwardWeight)
print("New Forward Weight : ", newForwardWeight)

```

## Practical 7a:

### Aim: Line Separation

You could imagine that you have two attributes describing an edible object like a fruit for example: "sweetness" and "sourness"

We could describe this by points in a two-dimensional space. The x axis for the sweetness and the y axis for the sourness. Imagine now that we have two fruits as points in this space, i.e. an orange at position (3.5, 1.8) and a lemon at (1.1, 3.9).

We could define dividing lines to define the points which are more lemon-like and which are more orange-like. The following program calculates and renders a bunch of lines. The red ones are completely unusable for this purpose, because they are not separating the classes. Yet, it is obvious that even the green ones are not all useful.

```
import numpy as np
import matplotlib.pyplot as plt

def create_distance_function(a, b, c):
    """ 0 = ax + by + c """
    def distance(x, y):
        """ returns tuple (d, pos)
            d is the distance
            If pos == -1 point is below the line,
            0 on the line and +1 if above the line
        """
        nom = a * x + b * y + c
        if nom == 0:
            pos = 0
        elif (nom < 0 and b < 0) or (nom > 0 and b > 0):
            pos = -1
        else:
            pos = 1
        return (np.absolute(nom) / np.sqrt(a ** 2 + b ** 2), pos)
    return distance

points = [(3.5, 1.8), (1.1, 3.9)]
fig, ax = plt.subplots()
ax.set_xlabel("sweetness")
ax.set_ylabel("sourness")
ax.set_xlim([-1, 6])
ax.set_ylim([-1, 8])
X = np.arange(-0.5, 5, 0.1)
colors = ["r", "#00FF00"]
# for the samples size = 10
for index, (x, y) in enumerate(points):
    if index == 0:
        ax.plot(x, y, "o", color="darkorange", markersize=size)
    else:
```

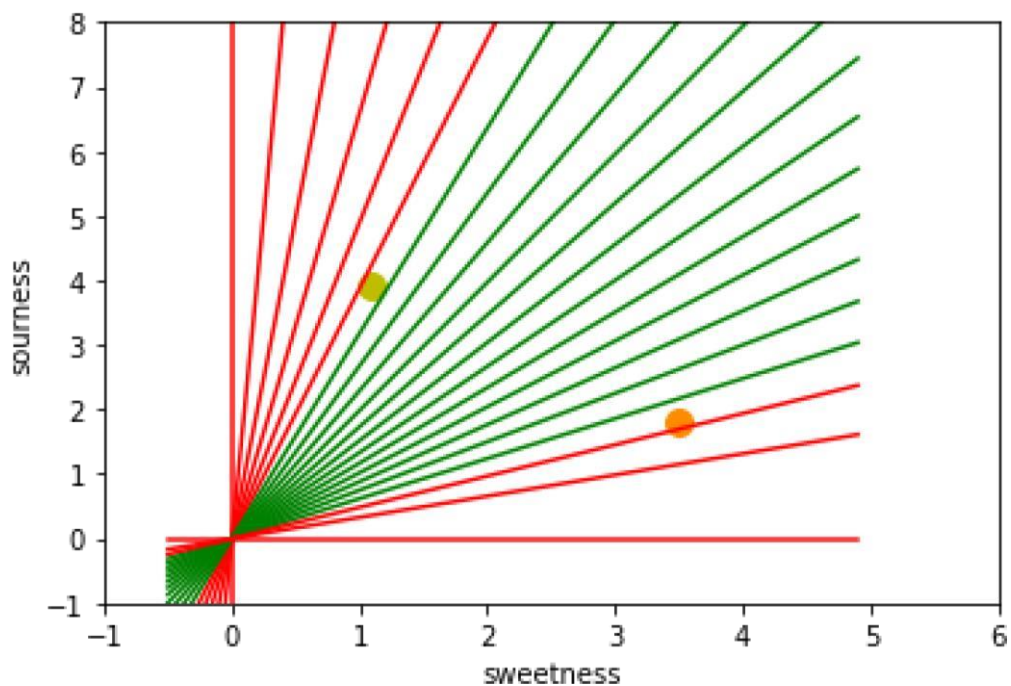
```

ax.plot(x, y, "oy", markersize=size)
step = 0.05
for x in np.arange(0, 1+step, step):
    slope = np.tan(np.arccos(x))
    dist4line1 = create_distance_function(slope, -1, 0)
    #print("x: ", x, "slope: ", slope)
    Y = slope * X

    results = []
    for point in points:
        results.append(dist4line1(*point))
    #print(slope, results)
    if (results[0][1] != results[1][1]):
        ax.plot(X, Y, "g-")
    else:
        ax.plot(X, Y, "r-")

plt.show()

```



### Practical 7b:

#### Aim: Hopfield Network model of associative memory

The Hopfield model (226), consists of a network of  $N$  neurons, labeled by a lower index  $i$ , with  $1 \leq i \leq N$ . Similar to some earlier models (335; 304; 549), neurons in the Hopfield model have only two states. A neuron  $i$  is 'ON' if its state variable takes the value  $S_i = +1$  and 'OFF' (silent) if  $S_i = -1$ . The dynamics evolves in discrete time with time steps  $\Delta t$ . There is no refractoriness and the duration of a time step is typically not specified. If we take  $\Delta t = 1\text{ms}$ , we can interpret  $S_i(t) = +1$  as an action potential of neuron  $i$  at time  $t$ . If we take  $\Delta t = 500\text{ms}$ ,  $S_i(t) = +1$  should rather be interpreted as an episode of high firing rate.

Neurons interact with each other with weights  $w_{ij}$ . The input potential of neuron  $i$ , influenced by the activity of other neurons is

$$h_i(t) = \sum_j w_{ij} S_j(t). \quad (17.2)$$

The input potential at time  $t$  influences the probabilistic update of the state variable  $S_i$  in the next time step:

$$\text{Prob}\{S_i(t+\Delta t) = +1 \mid h_i(t)\} = g(h_i(t)) = g(\sum_j w_{ij} S_j(t)) \quad (17.3)$$

where  $g$  is a monotonically increasing gain function with values between zero and one. A common choice is  $g(h) = 0.5[1 + \tanh(\beta h)]$  with a parameter  $\beta$ . For  $\beta \rightarrow \infty$ , we have  $g(h) = 1$  for  $h > 0$  and zero otherwise. The dynamics are therefore deterministic and summarized by the update rule

$$S_i(t+\Delta t) = \text{sgn}[h_i(t)] \quad (17.4)$$

For finite  $\beta$  the dynamics are stochastic. In the following we assume that in each time step all neurons are updated synchronously (parallel dynamics), but an update scheme where only one neuron is updated per time step is also possible.

#### Source code:

```
%matplotlib inline
from neurodynex.hopfield_network import network, pattern_tools, plot_tools

pattern_size = 5

# create an instance of the class HopfieldNetwork
hopfield_net = network.HopfieldNetwork(nr_neurons= pattern_size**2)
```

```

# instantiate a pattern factory
factory = pattern_tools.PatternFactory(pattern_size, pattern_size)

# create a checkerboard pattern and add it to the pattern list
checkerboard = factory.create_checkerboard() pattern_list
= [checkerboard]

# add random patterns to the list
pattern_list.extend(factory.create_random_pattern_list(nr_patterns=3, on_probability=0.5))
plot_tools.plot_pattern_list(pattern_list)
# how similar are the random patterns and the checkerboard? Check the overlaps
overlap_matrix = pattern_tools.compute_overlap_matrix(pattern_list)
plot_tools.plot_overlap_matrix(overlap_matrix)

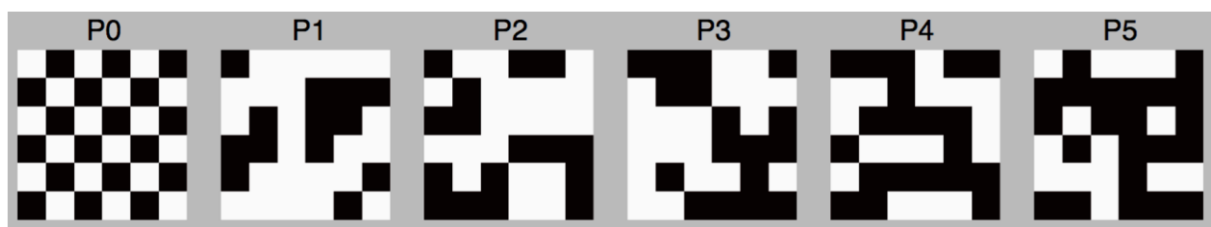
# let the hopfield network "learn" the patterns. Note: they are not stored #
explicitly but only network weights are updated !
hopfield_net.store_patterns(pattern_list)

# create a noisy version of a pattern and use that to initialize the network noisy_init_state
= pattern_tools.flip_n(checkerboard, nr_of_flips=4)
hopfield_net.set_state_from_pattern(noisy_init_state)

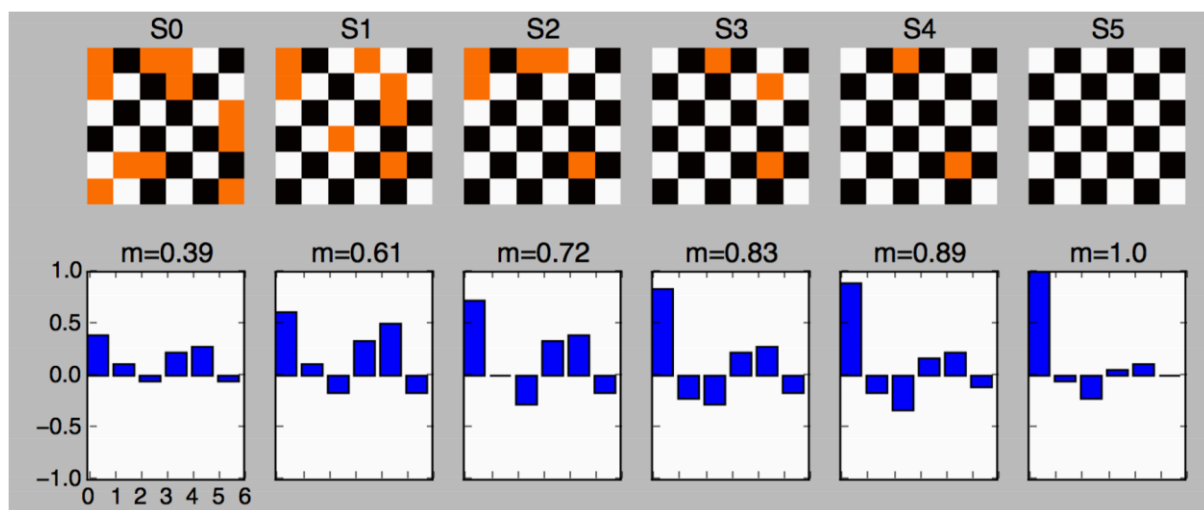
# from this initial state, let the network dynamics evolve.
states = hopfield_net.run_with_monitoring(nr_steps=4)

# each network state is a vector. reshape it to the same shape used to create the patterns.
states_as_patterns = factory.reshape_patterns(states)
# plot the states of the network
plot_tools.plot_state_sequence_and_overlap(states_as_patterns, pattern_list,
reference_idx=0, suptitle="Network dynamics")

```







## Practical 8a:

**Aim: Membership and Identity operators in, not in.**

```
# Python program to illustrate
# Finding common member in list
# without using 'in' operator

# Define a function() that takes two lists def
overlapping(list1,list2):
    c=0    d=0
    for i in list1:
        c+=1
    for i in list2:    d+=1
    for i in range(0,c):    for j in range(0,d):
        if(list1[i]==list2[j]):
            return 1
    return 0

list1=[1,2,3,4,5] list2=[6,7,8,9]
if(overlapping(list1,list2)):
    print("overlapping")
else:
    print("not overlapping")
```

---

```
# Python program to illustrate
# Finding common member in list
# without using 'in' operator

# Define a function() that takes two lists def
overlapping(list1,list2):
    c=0    d=0
    for i in list1:
        c+=1
    for i in list2:    d+=1
    for i in range(0,c):    for j in
range(0,d):    if(list1[i]==list2[j]):
        return 1
    return 0

list1=[1,2,3,4,5] list2=[6,7,8,9]
if(overlapping(list1,list2)):
    print("overlapping")
else:
    print("not overlapping")
```

---

## Practical 8b: Membership and Identity Operators is, is not

```
# Python program to illustrate the use
# of 'is' identity operator  x = 5 if
(type(x) is int):
    print ("true") else:
    print ("false")
```

---

```
# Python program to illustrate the
# use of 'is not' identity operator x
= 5.2 if (type(x) is not int):
    print ("true") else:
    print ("false")
```

## Practical 9a:

Find the ratios using fuzzy logic

```
pip install fuzzywuzzy
```

```
# Python code showing all the ratios together,
```

```
# make sure you have installed fuzzywuzzy module
```

```
from fuzzywuzzy import fuzz
```

```
from fuzzywuzzy import process
```

```
s1 = "I love fuzzysforfuzzys" s2 = "I am loving fuzzysforfuzzys" print  
("FuzzyWuzzy Ratio:", fuzz.ratio(s1, s2)) print  
("FuzzyWuzzyPartialRatio: ", fuzz.partial_ratio(s1, s2)) print  
("FuzzyWuzzyTokenSortRatio: ", fuzz.token_sort_ratio(s1, s2)) print  
("FuzzyWuzzyTokenSetRatio: ", fuzz.token_set_ratio(s1, s2)) print  
("FuzzyWuzzyWRatio: ", fuzz.WRatio(s1, s2),'\n\n')
```

```
# for process library, query = 'fuzzys for fuzzys' choices = ['fuzzy for fuzzy',  
'fuzzy fuzzy', 'g. for fuzzys'] print ("List of ratios: ") print  
(process.extract(query, choices), '\n') print ("Best among the above list:  
",process.extractOne(query, choices))
```

```
FuzzyWuzzy Ratio: 86  
FuzzyWuzzyPartialRatio: 86  
FuzzyWuzzyTokenSortRatio: 86  
FuzzyWuzzyTokenSetRatio: 87  
FuzzyWuzzyWRatio: 86  
  
List of ratios:  
[('g. for fuzzys', 95), ('fuzzy for fuzzy', 94), ('fuzzy fuzzy', 86)]  
Best among the above list: ('g. for fuzzys', 95)
```

## Practical 9b:

### Aim: Solve Tipping Problem using fuzzy logic

#### Fuzzy Control Systems: The Tipping Problem

---

The 'tipping problem' is commonly used to illustrate the power of fuzzy logic principles to generate complex behavior from a compact, intuitive set of expert rules.

If you're new to the world of fuzzy control systems, you might want to check out the 'Fuzzy Control Primer [<../userguide/fuzzy\\_control\\_primer.html>](http://userguide/fuzzy_control_primer.html)' before reading through this worked example.

#### The Tipping Problem

-----

Let's create a fuzzy control system which models how you might choose to tip at a restaurant. When tipping, you consider the service and food quality, rated between 0 and 10. You use this to leave a tip of between 0 and 25%.

We would formulate this problem as:

- \* Antecedents (Inputs)
  - 'service'
- \* Universe (ie, crisp value range): How good was the service of the wait staff, on a scale of 0 to 10?
- \* Fuzzy set (ie, fuzzy value range): poor, acceptable, amazing
  - 'food quality'
- \* Universe: How tasty was the food, on a scale of 0 to 10?
- \* Fuzzy set: bad, decent, great
- \* Consequents (Outputs)
  - 'tip'
- \* Universe: How much should we tip, on a scale of 0% to 25%
- \* Fuzzy set: low, medium, high
- \* Rules
  - IF the \*service\* was good \*or\* the \*food quality\* was good, THEN the tip will be high.
  - IF the \*service\* was average, THEN the tip will be medium.
  - IF the \*service\* was poor \*and\* the \*food quality\* was poor THEN the tip will be low.
- \* Usage
  - If I tell this controller that I rated:

- \* the service as 9.8, and
- \* the quality as 6.5, - it would recommend I leave:
- \* a 20.2% tip.

## Creating the Tipping Controller Using the skfuzzy control API

---

We can use the `skfuzzy` control system API to model this. First, let's define fuzzy variables **Code:**

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

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')

quality.automf(3)
service.automf(3)

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])

quality['average'].view()

service.view()
tip.view()

rule1 = ctrl.Rule(quality['poor'] | service['poor'], tip['low'])
rule2 = ctrl.Rule(service['average'], tip['medium'])
rule3 = ctrl.Rule(service['good'] | quality['good'], tip['high'])

rule1.view()

tipping_ctrl = ctrl.ControlSystem([rule1, rule2, rule3])

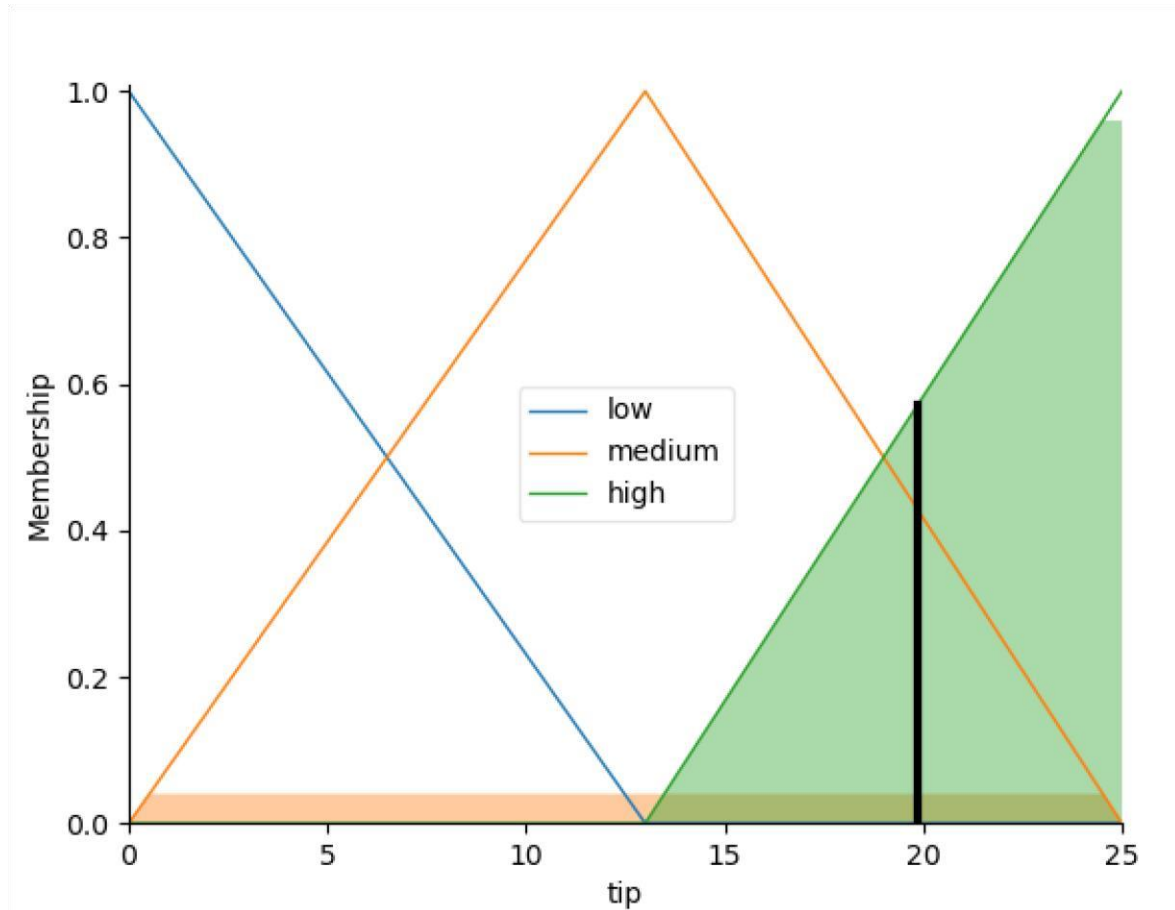
tipping = ctrl.ControlSystemSimulation(tipping_ctrl)
```

```
# Pass inputs to the ControlSystem using Antecedent labels with Pythonic API
tipping.input['quality'] = 6.5
tipping.input['service'] = 9.8
```

```
# Crunch the numbers
```

```
tipping.compute()
```

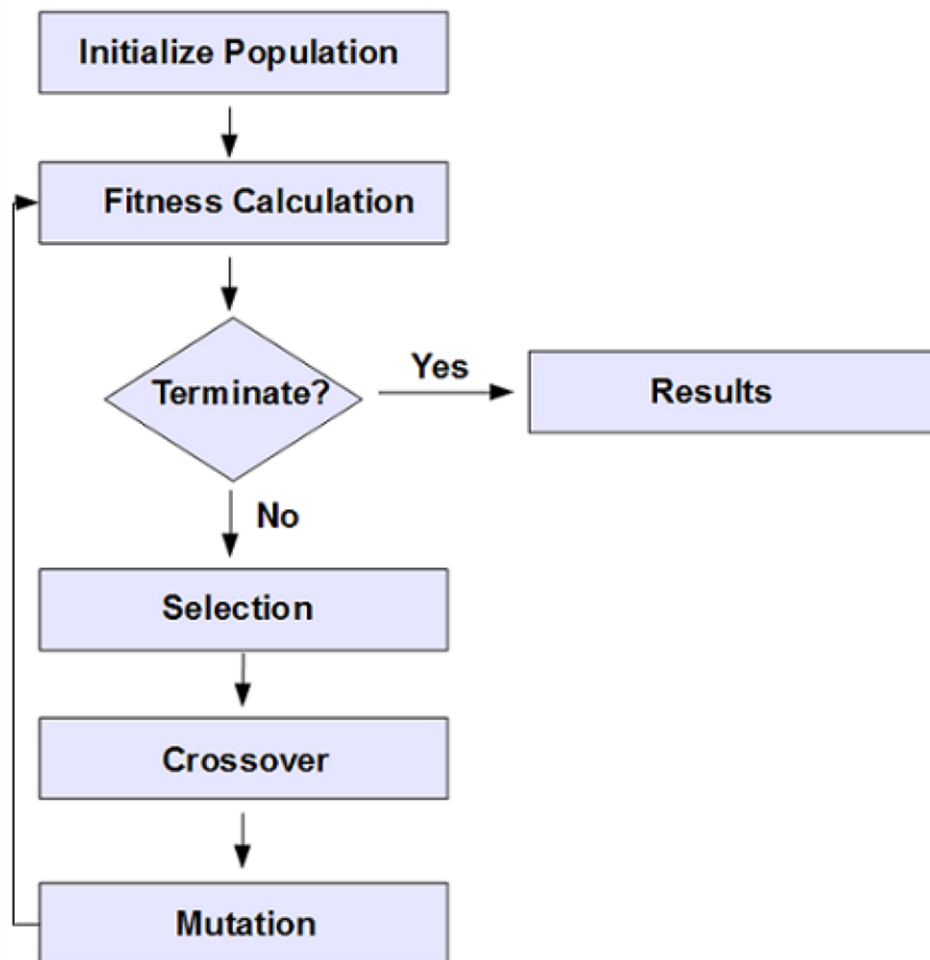
```
print tipping.output['tip']
tip.view(sim=tipping)
```



The resulting suggested tip is \*\* 19.8476\*\*

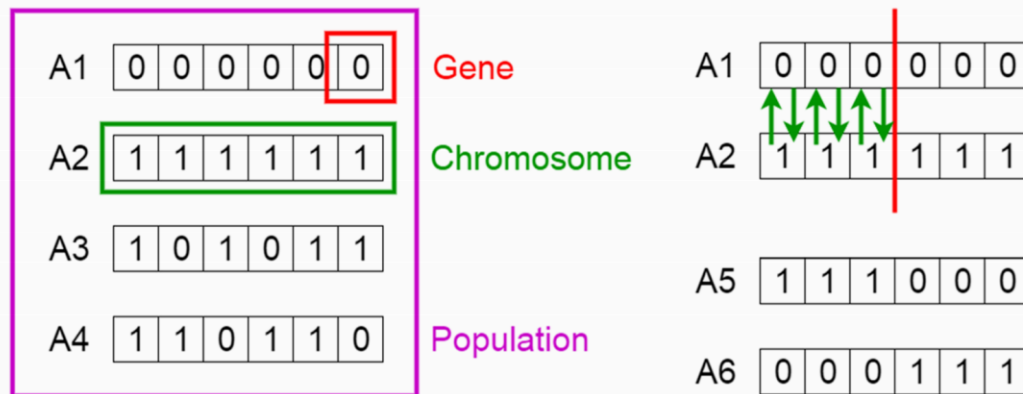
### Practical 10:

**Aim: Implementation of simple genetic algorithm**





# Genetic Algorithms



```
import random
```

```
# Number of individuals in each generation
POPULATION_SIZE = 100
```

```
# Valid genes
```

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

```
# Target string to be generated
```

```
TARGET = "Mithlesh Chauhan"
```

```
class Individual(object):
```

```
    """
```

```
    Class representing individual in population
```

```
    """
```

```
    def __init__(self, chromosome):
```

```
        self.chromosome = chromosome
```

```
        self.fitness = self.calculate_fitness()
```

```
    @classmethod    def
```

```
    mutated_genes(self):
```

```
        """
```

```

        create random genes for mutation
        """
        global GENES
        gene = random.choice(GENES)
        return gene

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

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

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

            # random probability
            prob = random.random()

            # if prob is less than 0.45, insert gene
            # from parent 1
            if prob < 0.45:
                child_chromosome.append(gp1)

            # if prob is between 0.45 and 0.90, insert
            # gene from parent 2
            elif prob < 0.90:
                child_chromosome.append(gp2)

            # otherwise insert random gene(mutate),
            # for maintaining diversity
            else:
                child_chromosome.append(self.mutated_genes())

        # create new Individual(offspring) using
        # generated chromosome for offspring
        return Individual(child_chromosome)

```

```

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

# Driver code
def main():
    global POPULATION_SIZE

    #current generation
    generation = 1

    found = False
    population = []

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

    while not found:

        # sort the population in increasing order of fitness score
        population = sorted(population, key = lambda x: x.fitness)

        # if the individual having lowest fitness score ie.
        # 0 then we know that we have reached to the target
        # and break the loop
        if population[0].fitness <= 0:
            found = True
            break

        # Otherwise generate new offsprings for new generation
        new_generation = []

        # Perform Elitism, that mean 10% of fittest population

```

```

        # goes to the next generation
        s
    =int((10*POPULATION_SIZE)/100)
    new_generation.extend(population[:s])

    # From 50% of fittest population, Individuals
    # will mate to produce offspring
    s
    =int((90*POPULATION_SIZE)/100)
    for _ in range(s):
        parent1 =random.choice(population[:50])
        parent2 =random.choice(population[:50])
        child
        =parent1.mate(parent2)
        new_generation.append(child)

    population =new_generation

    print("Generation: {} \tString: {} \tFitness:
    {}".format(generation, "".join(population[0].chromosome),population[0].fitness))
    generation +=1

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

if __name__ == '__main__':
    main()

```

Output:

```

Generation: 1  String: tO{"-?=jH[k8=B4]Oe@}  Fitness: 18
Generation: 2  String: tO{"-?=jH[k8=B4]Oe@}  Fitness: 18
Generation: 3  String: .#lRWf9k_Ifslw #O$k_  Fitness: 17
Generation: 4  String: .-1Rq?9mHqk3Wo]3rek_  Fitness: 16
Generation: 5  String: .-1Rq?9mHqk3Wo]3rek_  Fitness: 16
Generation: 6  String: A#ldW) #llkslwcVek)  Fitness: 14
Generation: 7  String: A#ldW) #llkslwcVek)  Fitness: 14
Generation: 8  String: (, o x _x%Rs=, 6Peek3  Fitness: 13
.
.
.

```

Generation: 29	String: I lope Geeks#o, Geeks	Fitness: 3
Generation: 30	String: I loMeGeeksfoBGeeks	Fitness: 2
Generation: 31	String: I love Geeksfo0Geeks	Fitness: 1
Generation: 32	String: I love Geeksfo0Geeks	Fitness: 1
Generation: 33	String: I love Geeksfo0Geeks	Fitness: 1
Generation: 34	String: I love GeeksforGeeks	Fitness: 0

**Practical 10b:**

### **Aim: Create two classes: City and Fitness using Genetic algorithm**

First create a City class that will allow us to create and handle our cities.

Create Population

<https://towardsdatascience.com/evolution-of-a-salesman-a-complete-genetic-algorithm-tutorial-for-python-6fe5d2b3ca35>

```
import numpy as np, random, operator, pandas as pd, matplotlib.pyplot as plt from
tkinter import Tk, Canvas, Frame, BOTH, Text import math class City:
```

```
    def __init__(self, x, y):
        self.x = x
        self.y = y

    def distance(self, city):
        xDis = abs(self.x - city.x)    yDis = abs(self.y
- city.y)    distance = np.sqrt((xDis
** 2) + (yDis ** 2))    return distance

    def __repr__(self):
        return "(" + str(self.x) + "," + str(self.y) + ")"

class Fitness:    def __init__(self, route):

        self.route = route
```

```

self.distance = 0      self.fitness=
0.0

    def routeDistance(self):      if
self.distance          ==0:
pathDistance = 0      for i in
range(0, len(self.route)):

        fromCity = self.route[i]
toCity = None          if i + 1 <
len(self.route):      toCity = self.route[i
+ 1]          else:

        toCity = self.route[0]
pathDistance += fromCity.distance(toCity)      self.distance
= pathDistance      return self.distance

    def routeFitness(self):      if self.fitness == 0:
self.fitness = 1 / float(self.routeDistance())      return
self.fitness
def createRoute(cityList):

    route = random.sample(cityList, len(cityList))
return route
def initialPopulation(popSize,
cityList):

    population = []      for i in
range(0, popSize):

        population.append(createRoute(cityList))
return population

```

```

def rankRoutes(population):
    fitnessResults = {}
    for i in range(0, len(population)):
        fitnessResults[i] = Fitness(population[i]).routeFitness()
    return sorted(fitnessResults.items(), key = operator.itemgetter(1), reverse = True)

def selection(popRanked, eliteSize):
    selectionResults = []
    df = pd.DataFrame(np.array(popRanked),
        columns=["Index", "Fitness"])
    df['cum_sum'] = df.Fitness.cumsum()
    df['cum_perc'] = 100*df.cum_sum/df.Fitness.sum()

    for i in range(0, eliteSize):
        selectionResults.append(popRanked[i][0])
    for i in range(0, len(popRanked) - eliteSize):
        pick = 100*random.random()
        for i in range(0, len(popRanked)):
            if pick <= df.iat[i,3]:
                selectionResults.append(popRanked[i][0])
                break
    return selectionResults

def matingPool(population, selectionResults):
    matingpool = []
    for i in range(0, len(selectionResults)):
        index = selectionResults[i]
        matingpool.append(population[index])
    return matingpool

```

```

def breed(parent1, parent2):
    child = []
    childP1 = []
    childP2 = []
    geneA = int(random.random()
    * len(parent1))
    geneB = int(random.random()
    * len(parent1))

    startGene = min(geneA, geneB)
    endGene = max(geneA, geneB)

    for i in range(startGene, endGene):
        childP1.append(parent1[i])

    childP2 = [item for item in parent2 if item not in childP1]

    child = childP1 + childP2
    return child

def breedPopulation(matingpool, eliteSize):
    children = []
    length = len(matingpool) - eliteSize
    pool = random.sample(matingpool, len(matingpool))

    for i in range(0, eliteSize):
        children.append(matingpool[i])

```



```

    for i in range(0, length):        child = breed(pool[i],
pool[len(matingpool)-i-1])        children.append(child)
    return children

```

```

def mutate(individual, mutationRate):
for swapped in range(len(individual)):
if(random.random() < mutationRate):

```

```

    swapWith = int(random.random() * len(individual))

```

```

        city1 = individual[swapped]        city2
= individual[swapWith]

```

```

        individual[swapped] = city2
individual[swapWith] = city1    return
individual

```

```

def mutatePopulation(population, mutationRate):

```

```

    mutatedPop = []

```

```

    for ind in range(0, len(population)):    mutatedInd =
mutate(population[ind],                    mutationRate)
mutatedPop.append(mutatedInd)    return mutatedPop

```

```

def nextGeneration(currentGen, eliteSize, mutationRate):
popRanked = rankRoutes(currentGen)    selectionResults =
selection(popRanked, eliteSize)    matingpool =

```

```

matingPool(currentGen, selectionResults)    children =
breedPopulation(matingpool, eliteSize) nextGeneration =
mutatePopulation(children, mutationRate)    return
nextGeneration

```

```

def geneticAlgorithm(population, popSize, eliteSize, mutationRate, generations):

```

```

    pop = initialPopulation(popSize, population)
    print("Initial distance: " + str(1 / rankRoutes(pop)[0][1]))

```

```

    for i in range(0, generations):

```

```

        pop = nextGeneration(pop, eliteSize, mutationRate)

```

```

    print("Final distance: " + str(1 / rankRoutes(pop)[0][1]))
    bestRouteIndex = rankRoutes(pop)[0][0]    bestRoute = pop[bestRouteIndex]
    return bestRoute

```

```

def geneticAlgorithmPlot(population, popSize, eliteSize, mutationRate, generations):

```

```

    pop = initialPopulation(popSize, population)
    progress = []    progress.append(1 / rankRoutes(pop)[0][1])

```

```

    for i in range(0, generations):

```

```

        pop = nextGeneration(pop, eliteSize, mutationRate)
        progress.append(1 / rankRoutes(pop)[0][1])
        plt.plot(progress)    plt.ylabel('Distance')
        plt.xlabel('Generation')    plt.show()
    def main():    cityList
    = []    for i in range(0,25):

```

```

cityList.append(City(x=int(random.random() * 200), y=int(random.random()
* 200)))    geneticAlgorithmPlot(population=cityList, popSize=100,
eliteSize=20,
mutationRate=0.01, generations=500) if __name__ == '__main__':
    main()

```

