Linear Algebra Take-home

Alekhya E (01FB15ECS032)

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Take Home-1

Linear Separability

PROBLEM STATEMENT: For the given set of samples,
1.S.T the data is linearly separable
b.S.T f1 = f2 is a decision boundary
c.Obtain the weight vector,w. S.T it is orthogonal to the decision boundary.
d.Suggest another decision boundary for the same data.
e.Compute the distance from the origin to the decision boundary
f.By transforming and normalizing the data, reconstruct the table and use perceptron learning algorithm to compute the new weight vector.

label no	f1	f2	class
1	0.5	3	X
2	1	3	X
3	0.5	2.5	X
4	1	2.5	X
5	1.5	2.5	X
6	4.5	1	O
7	5	1	O
8	4.5	0.5	O
9	5.5	0.5	O

Method used: I used perceptron algorithm and if the data converges in some finite amount of time(i.e in 1000 number of iterations) Then the data is said to be linearly separable.
Algorithm:

$Initializingthreshold_value \leftarrow 0$
$Initializinglearnrate \leftarrow 0.2i.eanynumberbetween0and1$
$Initializingierror \leftarrow -1$
$Initiallyinitializingtheweightarraywithrandomvaluesusingrandom.randint()withvaluesbetween0and1$
$Initializingtheconvergenceas0$ $count \leftarrow 0$
while $count \leq 1000andierror! = 0$ **do**
  $count \leftarrow count + 1$
  for $allthegivendataintrainingset$ **do**
    $output \leftarrow i[0] * wt[0] + i[1] * wt[1] + wt[2]$
    if $output > threshold_value$ **then**
      $output \leftarrow 1$
    else
      $output \leftarrow 0$
    end if
    $error \leftarrow expectedoutput - output$
    $ierror \leftarrow ierror + error * error$
    $weight1 \leftarrow weight1 + learnrate * error * f1_i$
    $weight2 \leftarrow weightt2 + learnrate * error * f2_i$
    $b \leftarrow b + learnrate * error$
  end for
  if $ierror = 0$ **then**
    $convergence \leftarrow 1$
    Exit while loop
  end if
end while
if $convergence = 1$ **then**
  The given data is linearly separable

else
    The given data is not linearly separable
end if

CODE

```
import math
import matplotlib.pyplot as plt
import random
import numpy as np
import statistics as stat

f=[[0.5,3],[1,3],[0.5,2.5],[1,2.5],[1.5,2.5],[4.5,1],[5,1],[4.5,0.5],[5.5,0.5]]
class1=[0,0,0,0,0,1,1,1,1]
threshold_value=0
learnrate=0.2
ierror=-1
count=0
weight=[]
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)


convergence=0
while(count<=1000 and ierror!=0):
        count=count+1
        j=0
        ierror=0
        for i in f:
             op=i[0]*weight[0]+i[1]*weight[1]+weight[2]
             if(op>threshold_value):
                     return 1
             else:
                     return 0

                 error=class1[j]-op
                 j=j+1
                 weight[0]=weight[0]+learnrate*error*i[0]
                 weight[1]=weight[1]+learnrate*error*i[1]
                 weight[2]=weight[2]+learnrate*error
                 ierror=ierror+(error*error)
        if(ierror==0):
            convergence=1
if(convergence==1):
    print("The given data is linearly separable")
    print("The number of iterations are given by:",count)
else:
    print("data is not linearly separable")
```

Result

Output:

The given data is linearly separable The number of iterations are given by:4

part-b

To show that f1=f2 is decision boundary

Method Used:

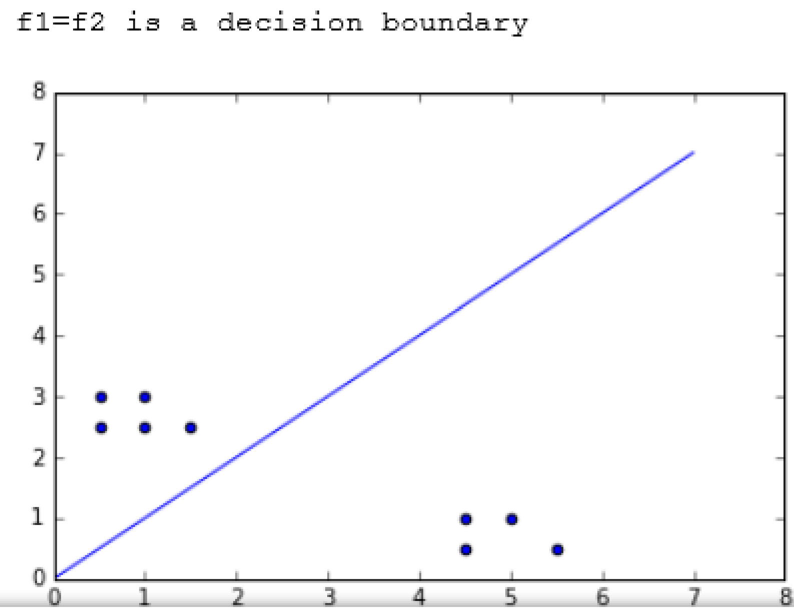
Basically for this problem the weight vector is 1x-1y=0 (f1-f2=0) with weight1=1 and weight2=-1 and with bias=0.For each data point in the given sample we find $.weigthvector^{transpose} sample$.If this value is greater than the threshold value then it belongs to class1 i.e (class 0 in this case) otherwise to class 0(i.e class X in this case)

Code:

```
%matplotlib inline
import math
import numpy as np
import statistics as stat
import matplotlib.pyplot as plt
import random
f=[[0.5,3],[1,3],[0.5,2.5],[1,2.5],[1.5,2.5],[4.5,1],[5,1],[4.5,0.5],[5.5,0.5]]
class1=[0,0,0,0,0,1,1,1,1]
learnrate=0.2
threshold_value=0
ierror=-1
weight=[]
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
count=0
bias=0
weight1=1
weight2=-1

 decision_boundary=1


j=0
for i in f:
     op=weight1*i[0]+weight2*i[1]+bias
          if(op>threshold_value):
                 return 1
          else:
                 return 0

          error=class1[j]-op
          j=j+1
          if(error!=0):
                  print("f1=f2 is not a decision boundary")
                  decision_boundary=0
                  break
if( decision_boundary==1):
    print("f1=f2 is a decision boundary")
    x1_p=np.linspace(0,7,7)
    y1_p=1*x1_p
    plt.plot(x1_p,y1_p)
    plt.scatter(f1,f2)
    plt.ylim(ymin=0)
    plt.xlim(xmin=0)
    plt.show()
```

RESULT: Output:

Graph



f1=f2 is a decision boundary.

PART-C

Show that the decision boundary is orthogonal to weight vector.

Method Used:

Basically considering two points p and q on the decision boundary f=$w^T * X + b$,and if $w^T(p-q) = 0$ i.e (the inner product of the weight vector with a vector in the direction of p and q)it implies that the weight vector is orthogonal to the decision boundary.

```
%matplotlib inline
import math
import numpy as np
import statistics as stat
import matplotlib.pyplot as plt
import random
f=[[0.5,3],[1,3],[0.5,2.5],[1,2.5],[1.5,2.5],[4.5,1],[5,1],[4.5,0.5],[5.5,0.5]]
class1=[0,0,0,0,0,1,1,1,1]
learnrate=0.2
threshold_value=0
ierror=-1
count=0
weight1=1
weight2=-1
weight=[]
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)

bias=0
#when p=(1, 1) and q=(2,2) which lie on the decision boundary f1=f2
point1=[1,1]
point2=[2,2]
weight1=1
weight2=-1
```

```python
bias=0

point2_diff_point1=[1,1]
weight_difference=point2_diff_point1[0]*weight1+point2_diff_point1[1]*weight2
if(weight_difference==0):
    print("The weight  vector is orthogonal to above decision boundary")
else:
    print("The weight  vector is not orthogonal to the above decision boundary")
```

Output:

The weight vector is orthogonal to above decision boundary

part-d

Suggest another decision boundary for the same data.

Method Used:

Actually used the perceptron algorithm to find another decision boundary for the given data points. Algorithm:

$Initializingthreshold_value \leftarrow 0$
$Initializinglearnrate \leftarrow 0.2i.eanynumberbetween0and1$
$Initializingierror \leftarrow -1$
$Initiallyinitializingtheweightarraywithrandomvaluesusingrandom.randint()withvaluesbetween0and1$
$Initializingtheconvergenceas0$ $count \leftarrow 0$
while $count \leq 1000andierror! = 0$ **do**
  $count \leftarrow count + 1$
  for $allthegivendataintrainingset$ **do**
    $output \leftarrow i[0] * weight[0] + i[1] * weight[1] + weight[2]$
    if $output > threshold_value$ **then**
      $output \leftarrow 1$
    else
      $output \leftarrow 0$
    end if
    $error \leftarrow expectedoutput - output$
    $ierror \leftarrow ierror + error * error$
    $weight1 \leftarrow weight1 + learnrate * error * f1_i$
    $weight2 \leftarrow weightt2 + learnrate * error * f2_i$
    $b \leftarrow b + learnrate * error$
  end for
  if $ierror = 0$ **then**
    $convergence \leftarrow 1$
    Exit while loop
  end if
end while
if $convergence = 1$ **then**
  The given data is linearly separable
else
  The given data is not linearly separable
end if

Code :

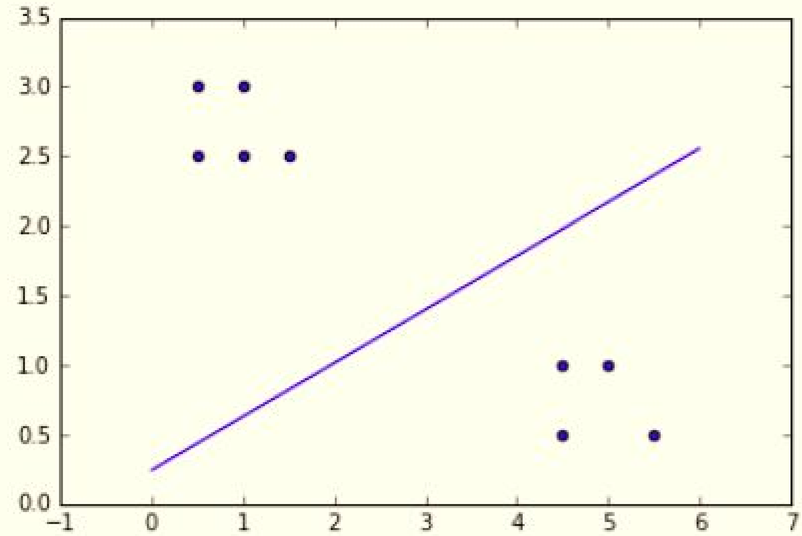
```python
import math
import numpy as np
import statistics as stat
```

```
import matplotlib.pyplot as plt
import random
f=[[0.5,3],[1,3],[0.5,2.5],[1,2.5],[1.5,2.5],[4.5,1],[5,1],[4.5,0.5],[5.5,0.5]]
class1=[0,0,0,0,0,1,1,1,1]
learnrate=0.2
threshold_value=0
ierror=-1
weight=[]
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
count=0


convergence=0
while(count<=10000 and ierror!=0):
        count=count+1
        j=0
        ierror=0
        for i in f:
            op=i[0]*weight[0]+i[1]*weight[1]+weight[2]
            if(op>threshold_value):
                   return 1
              else:
                  return 0

                error=class1[j]-op
                j=j+1
                weight[0]=weight[0]+learnrate*error*i[0]
                weight[1]=weight[1]+learnrate*error*i[1]
                weight[2]=weight[2]+learnrate*error
                ierror=ierror+(error*error)
        if(ierror==0):
            convergence=1

if(convergence==1):
    print("data is linearlly separable")
    print("decision boundary eqn is:" ,weight[0] ,"*x", weight[1], "*y","+",weight[2],"=0")
    f1=[i[0] for i in f]
    f2=[i[1] for i in f]
    plt.scatter(f1,f2)
    x_p=np.linspace(0,6,10)
    y_p=(-weight[2]-weight[0]*x_p)/weight[1]
    plt.plot(x_p,y_p)
    plt.show()
else:
    print("data is not linearlly separable")
```

Output:

Graph

```
w1= 0.791 0.945 0.784
decision boundary eqn is: 0.29100000000000004 *x -0.7550000000000002 *y + 0.18
```



part-e

Find the distance from origin to the separating hyperplane.

Method:

If line is given by the equation ax + by + c = 0, where a, b and c are real constants , the distance from the line to a point (x0,y0) is given by the formula Used the formula of finding distance of a point from a line. If a point is (x_0, y_0) then distance from a line Ax +By + C = 0 is (Ax_0 + By_0 + C)/($\sqrt{A^2 + B^2}$)
Here (x_0, y_0) is (0,0) and the hyperplane equation is same as the output of previous question.

Method used: So to find the distance of origin from decision boundary The distance d=weight[2]/math.sqrt(weight[0]**2+weig

Output:
The distance is given by 0.38534267477732

part-f

Problem Statement: By transforming and normalising the data, reconstruct the table and use perceptron learning algorithm to find the decision boundary.

Method:

Basically normalizing the data using the formula x-mean/standard deviation where x is the data point mean is the mean of the feature to which the datapoint belongs to and standard deviation is also the standard deviation of the feature to which the datapoint belongs to.
After normalizing the given data points applying perceptron to find the decision boundary.

Algorithm:

$Initializingthreshold_value \leftarrow 0$
$Initializinglearnrate \leftarrow 0.2i.eanynumberbetween0and1$
$Initializingierror \leftarrow -1$
$Initiallyinitializingtheweightarraywithrandomvaluesusingrandom.randint()withvaluesbetween0and1$
$Initializingtheconvergenceas0$ $count \leftarrow 0$
while $count \leq 1000andierror! = 0$ **do**
  $count \leftarrow count + 1$
  for $allthegivendataintrainingset$ **do**
    $output \leftarrow i[0] * wt[0] + i[1] * wt[1] + wt[2]$
    if $output > threshold_value$ **then**
      $output \leftarrow 1$
    else
      $output \leftarrow 0$
    end if
    $error \leftarrow expectedoutput - output$
    $ierror \leftarrow ierror + error * error$
    $weight1 \leftarrow weight1 + learnrate * error * f1_i$
    $weight2 \leftarrow weightt2 + learnrate * error * f2_i$
    $b \leftarrow b + learnrate * error$
  end for
  if $ierror = 0$ **then**

convergence $\leftarrow 1$
Exit while loop
end if
end while
if *convergence* $= 1$ **then**
The given data is linearly separable
else
The given data is not linearly separable
end if

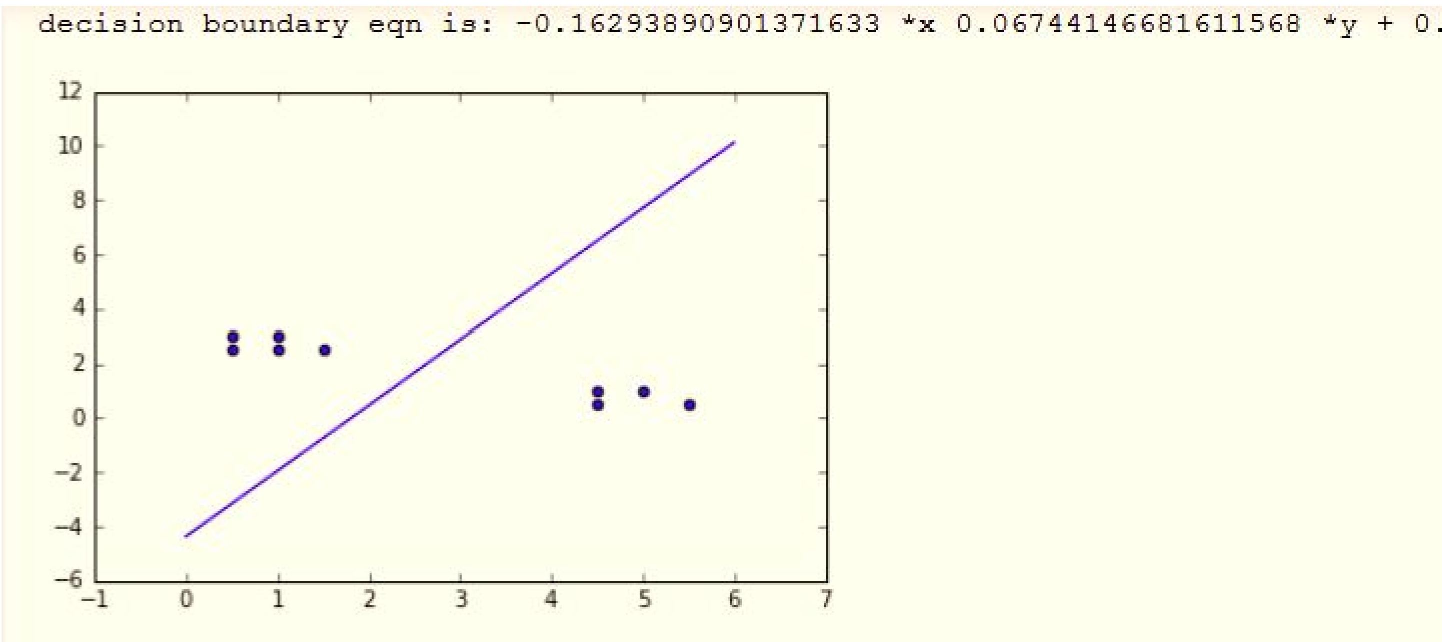
Code :

```
import math
import numpy as np
import statistics as stat
import matplotlib.pyplot as plt
import random
f=[[0.5,3],[1,3],[0.5,2.5],[1,2.5],[1.5,2.5],[4.5,1],[5,1],[4.5,0.5],[5.5,0.5]]
class1=[0,0,0,0,0,1,1,1,1]
f1=[i[0] for i in f]
f2=[i[1] for i in f]
stddev_of_f1=stat.stdev(f1)
stddev_of_f2=stat.stdev(f2)
mean_of_f1=stat.mean(f1)
mean_of_f2=stat.mean(f2)

nf=[]
for i in range(0,len(f1)):
    x=[]
    j=(f1[i]-mean_of_f1)/stddev_of_f1
    y=(f2[i]-mean_of_f2)/stddev_of_f2
    x.append(j)
    x.append(y)
    nf.append(x)
print(nf)

learnrate=0.2
threshold_value=0
ierror=-1
weight=[]
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
weight.append(random.randint(1,1000)/1000)
count=0


convergence=0
while(count<=10000 and ierror!=0):
        count=count+1
        j=0
        ierror=0
        for i in f:
                output=i[0]*weight[0]+i[1]*weight[1]+weight[2]

            if(output>threshold_value):
                    return 1
              else:
                     return 0
                error=class1[j]-output
                j=j+1
                weight[0]=weight[0]+learnrate*error*i[0]
                weight[1]=weight[1]+learnrate*error*i[1]
                weight[2]=weight[2]+learnrate*error
                ierror=ierror+(error*error)
        if(ierror==0):
```

```
            convergence=1
if(convergence==1):
    print("data is linearlly separable")
    print("decision boundary eqn is:" ,weight[0] ,"*x", weight[1], "*y","+",weight[2],"=0")
    f1=[i[0] for i in f]
    f2=[i[1] for i in f]
    plt.scatter(f1,f2)
    x_p=np.linspace(0,6,10)
    y_p=(-weight[2]-weight[0]*x_p)/weight[1]
    plt.plot(x_p,y_p)
    plt.show()
else:
    print("data is not linearlly separable")
```

Output:

Graph



Refrences:

`https://www.youtube.com/watch?v=1XkjVl-j8MM&t=9s`

`https://www.quora.com/How-can-I-know-whether-my-data-is-linearly-separable#!n=18`

`http://mathworld.wolfram.com/Point-PlaneDistance.html`

Take Home-2

Diagonalization Theorem

PROBLEM STATEMENT:

Prove the Diagonalization Theorem $P^{-1}AP = D$.Show that columns of P are eigen vectors of A.

ASSUMPTIONS:

$$1.A \in R^n$$

$$\lambda_1, \lambda_2......\lambda_n \in R$$

$$v_1, v_2, ...v_n \in R^n$$

The theorem holds good only if the matrix A is a square matrix.

SUMMARY:

Suppose A is a n by n matrix.For $P^{-1}APisadiagonalmatrixD$ D is a diagonal matrix where the diagonal elements are eigen values of A.P is a matrix containing eigen vectors of A.

Proof:

Basically from eigen-vector and eigen value relation we know that

$$Av_1 = \lambda_1 v_1, Av_2 = \lambda_2 v_2, Av_3 = \lambda_3 v_3, ...Av_n = \lambda_n v_n,$$

Putting eigen vectors in the columns of the matrix P.
AP=A*

$$\begin{bmatrix} v_1 & v_2 & v_3 & \dots & v_n \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

$$\begin{bmatrix} Av_1 & Av_2 & Av_3 & \dots & Av_n \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

$$\begin{bmatrix} \lambda_1 v_1 & \lambda_2 v_2 & \lambda_3 v_3 & \dots & \lambda_N v_n \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

Now if we observe the above matrix it is just a scalar multiple of the matrix P. So $AP =$

$$\begin{bmatrix} \lambda_1 v_1 & \lambda_2 v_2 & \lambda_3 v_3 & \dots & \lambda_N v_n \\ \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix}$$

So now AP=PD

AP=P x

$$\begin{bmatrix} lambda_1 & & \\ & \ddots & \\ & & lambda_n \end{bmatrix}$$

$P^{-1}AP = D$

The above given matrix a Diagonal matrix with the eigen values of matrix A on the diagonal. Hence proved that $P^{-1}AP = D$.Columns of P are eigen vectors of A.

Refrences:

Linear Algebra and its Applications by Gilbert Strang

Take Home-3

Problem Statement: $||A||_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} |a_{ji}| isamatrixnorm$

Proof:

To prove that $||A||_o$ is a matrix norm , the following properties has to be satisfied:

1. Non - negativity of matrix norm i.e matrix norm is always positive.

2.$||\alpha A||_o = \alpha ||A||_o$

3.$||A||_o = 0$, if and only if all the elements in the matrix are 0.

4.$||A + B||_o <= ||A||_o + ||B||_o$

5.$||A.B||_o <= ||A||_o.||B||_o$

Property number 1: Since the matrix norm is sum of all the elements row-wise and we are considering the absolute value of this.So the matrix norm is always positive.

Property 2:
$||\alpha A_O|| = \sum_{i=1}^{n} \sum_{j=1}^{n} |\alpha a_{ij}|$

Since α is just a scalar we can take it out. $||\alpha A_O|| = |\alpha|(\sum_{i=1}^{n} \sum_{j=1}^{n} |a_{ij}|)$

Property 3:
Since the matrix norm is sum of all the elements row-wise and we are considering the absolute value of this.So the matrix norm is always positive.But it will be 0 if all the elements of the matrix A are 0.

Property 4:

We use Cauchy Schwartz inequality to prove this property.

$$||A + B||_o = \sum_{i=1}^{n} \sum_{j=1}^{n} |a_{ij} + b_{ij}|$$
$$\leqslant \sum_{i=1}^{n} \sum_{j=1}^{n} |a_{ji}| + \sum_{i=1}^{n} \sum_{j=1}^{n} |b_{ji}|$$

$<= ||A|| + ||B||$
property-5
$||A.B||_o <= ||A||_o.||B||_o$

$$= \sum_{i=1}^{n} \sum_{j=1}^{n} \left[\sum_{k=1}^{n} |a_{jk} b_{ki}| \right]$$
$$\leqslant \sum_{i=1}^{n} \sum_{j=1}^{n} \left[\sum_{k=1}^{n} |a_{jk}| [\sum_{k=1}^{n} |b_{ki}| \right]$$
$$\leqslant \sum_{i=1}^{n} \sum_{k=1}^{n} [a_{jk}| * \sum_{i=1}^{n} \sum_{k=1}^{n} [b_{ki}|$$
$$\leqslant \sum_{k=1}^{n} \sum_{j=1}^{n} [a_{jk}| * \sum_{i=1}^{n} \sum_{k=1}^{n} b_{ki}|$$
$$\leqslant ||A|| * ||B||$$

Hence proved that $||A||_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} |a_{ji}|$ is a matrix norm since it satisfies all the properties of the matrix norm.

REFRENCES:

Numerical Analysis R L Burden and J D Faires

Take Home-4

Probability problem

Problem Statement

Suppose that an object can be at any one of the (n+1) equally spaced points $x_0, x_1, ..., x_n$. When an object is at location x_i , it is equally likely to move to either x_{i-1} or x_{i+1} and cant directly move to any other location. Consider the probabilities ${p_i}_{i=0}^{n}$ that an object starting at location x_i will reach the left end point x_0 before reaching the right end point. Clearly p_o=1 and p_n=0. Also, $p_i = 0.5p_{i-1} + 0.5p_{i+1}$ for all i=1,2,...n-1.

Show that:
1.
$$\begin{bmatrix} 1 & -0.5 & 0 & 0 & 0 & \dots & 0 \\ -0.5 & 1 & -0.5 & 0 & 0 & \dots & 0 \\ 0 & -0.5 & 1 & -0.5 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & -0.5 & 1 \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ \vdots \\ p_{n-1} \end{bmatrix} = \begin{bmatrix} 0.5 \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

2.Solve the system for n=100, and n=1000

3.Change the probabilities α and $1 - \alpha$ for movement to left or right. Derive the linear system similar to one in (1).

4.Repeat (2) with α =1/3.

a]Part-1:

Multplying both the matrices we get,

$$\begin{bmatrix} P_1 - 1/2P_2 \\ -1/2P_1 + P_2 - P_3 \\ -1/2P_2 + P_3 \\ -1/2P_{n-1} \\ . \\ . \\ . \\ . \\ . \\ -1/2P_{n-2} + P_{n-1} \end{bmatrix}$$

Now from the given equation $P_i = 1/2P_{i-1} + 1/2P_{i+1}$ Now by solving these simultaneous linear equations we ger,

So for i=1 $P_1 = 1/2P_0 + 1/2P_2$

$P_1 - 1/2P_2 = 1/2P_0$

Since the value of P_0 is 1

So $P_1 - 1/2P_2 = 1/2$

Then for i=2

$P_2 = 1/2P_1 + 1/2P_3$

$P_2 - 1/2P_1 - 1/2P_3 = 0$

Similarly for i=3,4.....n

It is 0 So the matrix is

$$\begin{bmatrix} 1/2 \\ 0 \\ 0 \\ 0 \\ . \\ . \\ . \\ . \\ 0 \end{bmatrix}$$

Hence proved.

part-b:

Assumptions:
Here the input is taken dynamically from the user.So the code below holds good for all the values of n i.e for n=100 and n=1000.

Algorithm:

Used Gaussian elimination to find the to solve the given system.

Basically the programm itself generates the given above matrix depending on the input given by the user (i.e n=100 or 1000 in this case)

Gaussian Elimination.

for j=0,...,n **do**
  for i=0,...,n **do**
    if $i > j$ **then**
      $c = a[i][j]/a[j][j]$
      Dividing each element by diagonal to generate a upper triangular matrix.
      for k=0,...,n **do**
        $a[i][k] = a[i][k] - c * a[j][k]$
      end for
    end if
  end for
end for
$x[n-1] = a[n-1][n]/a[n-1][n-1]$
for i=n-1,...,0 **do**
  $Initializesum \leftarrow 0.$
  for j=i+1,...,n-1 **do**
    $sum = sum + a[i][j] * x[j]$
  end for
  $x[i] = (a[i][n] - sum)/a[i][i]$
end for

CODE

```
#include<stdio.h>
#include<stdlib.h>
int input(int n)
{
  int i;
  int j;

  double **a=(double **)malloc((n+1)*sizeof(double *));
  for(i=0;i<=n;i++)
  {
    a[i]=(double *)malloc(n*sizeof(double));
  }
    //For generating the input matrix
  for(i=0;i<=n-1;i++)
  {
    for(j=0;j<=n;j++)
    {
      if(i==j)
      {
        a[i][j]=1;
      }
      else if((j==i+1 || j==i-1) && j!=n)
      {
        a[i][j]=-0.5;
      }
      else if(j!=n)
      {
        a[i][j]=0;
      }
      else if(j==n && i==0)
        a[i][j]=0.5;
      else if (j==n && i!=0)
        a[i][j]=0;
    }
  }
  int k;
```

```
  float c;
    //Gaussian elimination-for generating upper triangular matrix.
       for(j=0; j<=n; j++)
        {
        for(i=0; i<=n; i++)
        {
            if(i>j)
            {
                c=a[i][j]/a[j][j];
                for(k=0; k<=n+1; k++)
                {
                    a[i][k]=a[i][k]-c*a[j][k];
                }
            }
        }
        }
  for(i=0;i<=n-1;i++)
  {
    for(j=0;j<=n;j++)
    {
      printf("%2f  ",a[i][j]);
    }
    printf("\n");
  }

  double *x=(double *)malloc((n)*sizeof(double));

    x[n-1]=a[n-1][n]/a[n-1][n-1]; int sum;
  //Back-substitution :to find the solution i.e to get the values of probabilities in this
    case.
    for(i=n-1; i>=0; i--)
    {
        sum=0;
        for(j=i+1; j<=n-1; j++)
        {
            sum=sum+a[i][j]*x[j];
        }
        x[i]=(a[i][n]-sum)/a[i][i];
    }
    printf("\nThe solution is: \n");
    for(i=0; i<n; i++)

        printf("\np%d=%f\t",i+1,x[i]);



    return 0 ;

}
int main(){
    int n;
    int i;
    scanf("%d",&n);
input(n-1);



}
```

INPUT: n=100 and n=1000 RESULT : By solving the system for n=100
The solution is:

p1=0.500000 p2=0.333333 p3=0.250000 p4=0.200000 p5=0.166667 p6=0.142857 p7=0.125000 p8=0.111111 p9=0.100000 p10=0.090909 p11=0.083333 p12=0.076923 p13=0.071429 p14=0.066667 p15=0.062500 p16=0.058824 p17=0.055556 p18=0.052632 p19=0.050000 p20=0.047619 p21=0.045455 p22=0.043478 p23=0.041667 p24=0.040000 p25=0.038462 p26=0.037037 p27=0.035714 p28=0.034483 p29=0.033333

p30=0.032258 p31=0.031250 p32=0.030303 p33=0.029412 p34=0.028571 p35=0.027778 p36=0.027027
p37=0.026316 p38=0.025641 p39=0.025000 p40=0.024390 p41=0.023810 p42=0.023256 p43=0.022727
p44=0.022222 p45=0.021739 p46=0.021277 p47=0.020833 p48=0.020408 p49=0.020000 p50=0.019608
p51=0.019231 p52=0.018868 p53=0.018519 p54=0.018182 p55=0.017857 p56=0.017544 p57=0.017241
p58=0.016949 p59=0.016667 p60=0.016393 p61=0.016129 p62=0.015873 p63=0.015625 p64=0.015385
p65=0.015152 p66=0.014925 p67=0.014706 p68=0.014493 p69=0.014286 p70=0.014085 p71=0.013889
p72=0.013699 p73=0.013514 p74=0.013333 p75=0.013158 p76=0.012987 p77=0.012821 p78=0.012658
p79=0.012500 p80=0.012346 p81=0.012195 p82=0.012048 p83=0.011905 p84=0.011765 p85=0.011628
p86=0.011494 p87=0.011364 p88=0.011236 p89=0.011111 p90=0.010989 p91=0.010870 p92=0.010753
p93=0.010638 p94=0.010526 p95=0.010417 p96=0.010309 p97=0.010204 p98=0.010101 p99=0.010000
By solving the system for n=1000

The solution is:
p1=0.500000 p2=0.333333 p3=0.250000 p4=0.200000 p5=0.166667 p6=0.142857 p7=0.125000 p8=0.111111
p9=0.100000 p10=0.090909 p11=0.083333 p12=0.076923 p13=0.071429 p14=0.066667 p15=0.062500
p16=0.058824 p17=0.055556 p18=0.052632 p19=0.050000 p20=0.047619 p21=0.045455 p22=0.043478
p23=0.041667 p24=0.040000 p25=0.038462 p26=0.037037 p27=0.035714 p28=0.034483 p29=0.033333
p30=0.032258 p31=0.031250 p32=0.030303 p33=0.029412 p34=0.028571 p35=0.027778 p36=0.027027
p37=0.026316 p38=0.025641 p39=0.025000 p40=0.024390 p41=0.023810 p42=0.023256 p43=0.022727
p44=0.022222 p45=0.021739 p46=0.021277 p47=0.020833 p48=0.020408 p49=0.020000 p50=0.019608
p51=0.019231 p52=0.018868 p53=0.018519 p54=0.018182 p55=0.017857 p56=0.017544 p57=0.017241
p58=0.016949 p59=0.016667 p60=0.016393 p61=0.016129 p62=0.015873 p63=0.015625 p64=0.015385
p65=0.015152 p66=0.014925 p67=0.014706 p68=0.014493 p69=0.014286 p70=0.014085 p71=0.013889
p72=0.013699 p73=0.013514 p74=0.013333 p75=0.013158 p76=0.012987 p77=0.012821 p78=0.012658
p79=0.012500 p80=0.012346 p81=0.012195 p82=0.012048 p83=0.011905 p84=0.011765 p85=0.011628
p86=0.011494 p87=0.011364 p88=0.011236 p89=0.011111 p90=0.010989 p91=0.010870 p92=0.010753
p93=0.010638 p94=0.010526 p95=0.010417 p96=0.010309 p97=0.010204 p98=0.010101 p99=0.010000
p100=0.009901 p101=0.009804 p102=0.009709 p103=0.009615 p104=0.009524 p105=0.009434
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p124=0.008000 p125=0.007937 p126=0.007874 p127=0.007813 p128=0.007752 p129=0.007692
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p898=0.001112 p899=0.001111 p900=0.001110 p901=0.001109 p902=0.001107 p903=0.001106
p904=0.001105 p905=0.001104 p906=0.001103 p907=0.001101 p908=0.001100 p909=0.001099

p910=0.001098	p911=0.001096	p912=0.001095	p913=0.001094	p914=0.001093	p915=0.001092
p916=0.001090	p917=0.001089	p918=0.001088	p919=0.001087	p920=0.001086	p921=0.001085
p922=0.001083	p923=0.001082	p924=0.001081	p925=0.001080	p926=0.001079	p927=0.001078
p928=0.001076	p929=0.001075	p930=0.001074	p931=0.001073	p932=0.001072	p933=0.001071
p934=0.001069	p935=0.001068	p936=0.001067	p937=0.001066	p938=0.001065	p939=0.001064
p940=0.001063	p941=0.001062	p942=0.001060	p943=0.001059	p944=0.001058	p945=0.001057
p946=0.001056	p947=0.001055	p948=0.001054	p949=0.001053	p950=0.001051	p951=0.001050
p952=0.001049	p953=0.001048	p954=0.001047	p955=0.001046	p956=0.001045	p957=0.001044
p958=0.001043	p959=0.001042	p960=0.001041	p961=0.001039	p962=0.001038	p963=0.001037
p964=0.001036	p965=0.001035	p966=0.001034	p967=0.001033	p968=0.001032	p969=0.001031
p970=0.001030	p971=0.001029	p972=0.001028	p973=0.001027	p974=0.001026	p975=0.001025
p976=0.001024	p977=0.001022	p978=0.001021	p979=0.001020	p980=0.001019	p981=0.001018
p982=0.001017	p983=0.001016	p984=0.001015	p985=0.001014	p986=0.001013	p987=0.001012
p988=0.001011	p989=0.001010	p990=0.001009	p991=0.001008	p992=0.001007	p993=0.001006
p994=0.001005	p995=0.001004	p996=0.001003	p997=0.001002	p998=0.001001	p999=0.001000

part-c

From changing the probabilities to

$$\alpha and (1-\alpha) \tag{1}$$

for movement to the left or right.

$$P_i = \alpha P_{i-1} + (1-\alpha) P_{i+1} \tag{2}$$

Solving the equation For i=1

$$P_1 = \alpha P_0 + (1-\alpha) P_2 \tag{3}$$

For i=2

$$P_2 = \alpha P_1 + (1-\alpha) P_3 \tag{4}$$

For i=3

$$P_3 = \alpha P_2 + (1-\alpha) P_4 \tag{5}$$

For i=4

$$P_4 = \alpha P_3 + (1-\alpha) P_5 \tag{6}$$

For i=n-1

$$P_{n-1} = \alpha P_{n-2} + (1-\alpha) P_n \tag{7}$$

Since the equations are nothing but linear transformations.Hence writing the above equations in terms of matrix

$$\begin{bmatrix} 1 & -(1-\alpha) & 0 & \dots & 0 \\ \alpha & -1 & (1-\alpha) & \ddots & 0 \\ 0 & \alpha & \ddots & 1 & (1-\alpha) \\ 0 & 0 & \alpha & \ddots -1 & \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & 0 & \alpha & \dots & (1-\alpha) \end{bmatrix}$$

part-d

Assumptions:
Here the input is taken dynamically from the user.So the code below holds good for all the values of n i.e for n=100 and n=1000.

Used Gaussian elimination to find the to solve the given system.
Basically the programm itself generates the matrix with the value of alpha as 0.333 depending on the input given by the user (i.e n=100 or 1000 in this case)

Gaussian Elimination.

for j=0,...,n **do**
  for i=0,...,n **do**
    if $i > j$ **then**
      $c = a[i][j]/a[j][j]$
      Dividing each element by diagonal to generate a upper triangular matrix.
      for k=0,...,n **do**
        $a[i][k] = a[i][k] - c * a[j][k]$
      end for
    end if
  end for
end for
$x[n-1] = a[n-1][n]/a[n-1][n-1]$

for i=n-1,...,0 **do**
  $Initialize sum \leftarrow 0.$
  for j=i+1,...,n-1 **do**
    $sum = sum + a[i][j] * x[j]$
  end for
  $x[i] = (a[i][n] - sum)/a[i][i]$
end for

CODE

```
#include<stdio.h>


#include<stdlib.h>




int input(int n)
{
  int i;
  int j;
  //int *a;
  double **a=(double **)malloc((n+1)*sizeof(double *));
  for(i=0;i<=n;i++)
  {
    a[i]=(double *)malloc(n*sizeof(double));
  }
     //For generating the input matrix
  for(i=0;i<=n-1;i++)
  {
    for(j=0;j<=n;j++)
    {
      if(i==j)
      {
        a[i][j]=1;
      }
      else if((j==i+1) && j!=n)
      {
        a[i][j]=-0.6666;
      }
      else if(j==i-1 && j!=n)
        a[i][j]=-0.3333;
      else if(j!=n)
      {
        a[i][j]=0;
      }
      else if(j==n && i==0)
        a[i][j]=0.3333;
      else if (j==n && i!=0)
        a[i][j]=0;
    }
  }
  for(i=0;i<=n;i++)
  {
    for(j=0;j<=n;j++)
    {
      printf("%f\t",a[i][j]);
    }
printf("\n");
  }

  int k;
  float c;
    //Gausian elimination:To generate a upper traingular matrix.
       for(j=0; j<=n; j++)
```

```c
        {
        for(i=0; i<=n; i++)
        {
            if(i>j)
            {
                c=a[i][j]/a[j][j];
                for(k=0; k<=n+1; k++)
                {
                    a[i][k]=a[i][k]-c*a[j][k];
                }
            }
        }
        }
  for(i=0;i<=n-1;i++)
  {
    for(j=0;j<=n;j++)
    {
      printf("%2f  ",a[i][j]);
    }
    printf("\n");
  }

  double *x=(double *)malloc((n)*sizeof(double));

    x[n-1]=a[n-1][n]/a[n-1][n-1]; int sum;
  /Back-substitution :to find the solution i.e to get the values of probabilities in this case.
    for(i=n-1; i>=0; i--)
    {
        sum=0;
        for(j=i+1; j<=n-1; j++)
        {
            sum=sum+a[i][j]*x[j];
        }
        x[i]=(a[i][n]-sum)/a[i][i];
    }
    printf("\nThe solution is: \n");
    for(i=0; i<n; i++)

        printf("\np%d=%f\t",i+1,x[i]);



    return 0 ;

}
int main(){
    int n;
    int i;
    scanf("%d",&n);
input(n-1);

}
```

INPUT: INPUT: n=100 and n=1000 RESULT : By solving the system for n=100
The solution is:
p1=0.333300 p2=0.142820 p3=0.066636 p4=0.032236 p5=0.015858 p6=0.007864 p7=0.003916 p8=0.001953 p9=0.000975 p10=0.000487 p11=0.000244 p12=0.000122 p13=0.000061 p14=0.000030 p15=0.000015 p16=0.000008 p17=0.000004 p18=0.000002 p19=0.000001 p20=0.000000 p21=0.000000 p22=0.000000 p23=0.000000 p24=0.000000 p25=0.000000 p26=0.000000 p27=0.000000 p28=0.000000 p29=0.000000 p30=0.000000 p31=0.000000 p32=0.000000 p33=0.000000 p34=0.000000 p35=0.000000 p36=0.000000 p37=0.000000 p38=0.000000 p39=0.000000 p40=0.000000 p41=0.000000 p42=0.000000 p43=0.000000 p44=0.000000 p45=0.000000 p46=0.000000 p47=0.000000 p48=0.000000 p49=0.000000 p50=0.000000 p51=0.000000 p52=0.000000 p53=0.000000 p54=0.000000 p55=0.000000 p56=0.000000 p57=0.000000 p58=0.000000 p59=0.000000 p60=0.000000 p61=0.000000 p62=0.000000 p63=0.000000 p64=0.000000

p65=0.000000 p66=0.000000 p67=0.000000 p68=0.000000 p69=0.000000 p70=0.000000 p71=0.000000 p72=0.000000 p73=0.000000 p74=0.000000 p75=0.000000 p76=0.000000 p77=0.000000 p78=0.000000 p79=0.000000 p80=0.000000 p81=0.000000 p82=0.000000 p83=0.000000 p84=0.000000 p85=0.000000 p86=0.000000 p87=0.000000 p88=0.000000 p89=0.000000 p90=0.000000 p91=0.000000 p92=0.000000 p93=0.000000 p94=0.000000 p95=0.000000 p96=0.000000 p97=0.000000 p98=0.000000 p99=0.000000

For n=1000

The solution is:
p1= 0.333300 p2= 0.142820 p3= 0.066636 p4= 0.032236 p5= 0.015858 p6= 0.007864 p7= 0.003916 p8= 0.001953 p9= 0.000975 p10= 0.000487 p11= 0.000244 p12= 0.000122 p13= 0.000061 p14= 0.000030 p15= 0.000015 p16= 0.000008 p17= 0.000004 p18= 0.000002 p19= 0.000001 p20= 0.000000 p21= 0.000000 p22= 0.000000 p23= 0.000000 p24= 0.000000 p25= 0.000000 p26= 0.000000 p27= 0.000000 p28= 0.000000 p29= 0.000000 p30= 0.000000 p31= 0.000000 p32= 0.000000 p33= 0.000000 p34= 0.000000 p35= 0.000000 p36= 0.000000 p37= 0.000000 p38= 0.000000 p39= 0.000000 p40= 0.000000 p41= 0.000000 p42= 0.000000 p43= 0.000000 p44= 0.000000 p45= 0.000000 p46= 0.000000 p47= 0.000000 p48= 0.000000 p49= 0.000000 p50= 0.000000 p51= 0.000000 p52= 0.000000 p53= 0.000000 p54= 0.000000 p55= 0.000000 p56= 0.000000 p57= 0.000000 p58= 0.000000 p59= 0.000000 p60= 0.000000 p61= 0.000000 p62= 0.000000 p63= 0.000000 p64= 0.000000 p65= 0.000000 p66= 0.000000 p67= 0.000000 p68= 0.000000 p69= 0.000000 p70= 0.000000 p71= 0.000000 p72= 0.000000 p73= 0.000000 p74= 0.000000 p75= 0.000000 p76= 0.000000 p77= 0.000000 p78= 0.000000 p79= 0.000000 p80= 0.000000 p81= 0.000000 p82= 0.000000 p83= 0.000000 p84= 0.000000 p85= 0.000000 p86= 0.000000 p87= 0.000000 p88= 0.000000 p89= 0.000000 p90= 0.000000 p91= 0.000000 p92= 0.000000 p93= 0.000000 p94= 0.000000 p95= 0.000000 p96= 0.000000 p97= 0.000000 p98= 0.000000 p99= 0.000000 p100= 0.000000 p101= 0.000000 p102= 0.000000 p103= 0.000000 p104= 0.000000 p105= 0.000000 p106= 0.000000 p107= 0.000000 p108= 0.000000 p109= 0.000000 p110= 0.000000 p111= 0.000000 p112= 0.000000 p113= 0.000000 p114= 0.000000 p115= 0.000000 p116= 0.000000 p117= 0.000000 p118= 0.000000 p119= 0.000000 p120= 0.000000 p121= 0.000000 p122= 0.000000 p123= 0.000000 p124= 0.000000 p125= 0.000000 p126= 0.000000 p127= 0.000000 p128= 0.000000 p129= 0.000000 p130= 0.000000 p131= 0.000000 p132= 0.000000 p133= 0.000000 p134= 0.000000 p135= 0.000000 p136= 0.000000 p137= 0.000000 p138= 0.000000 p139= 0.000000 p140= 0.000000 p141= 0.000000 p142= 0.000000 p143= 0.000000 p144= 0.000000 p145= 0.000000 p146= 0.000000 p147= 0.000000 p148= 0.000000 p149= 0.000000 p150= 0.000000 p151= 0.000000 p152= 0.000000 p153= 0.000000 p154= 0.000000 p155= 0.000000 p156= 0.000000 p157= 0.000000 p158= 0.000000 p159= 0.000000 p160= 0.000000 p161= 0.000000 p162= 0.000000 p163= 0.000000 p164= 0.000000 p165= 0.000000 p166= 0.000000 p167= 0.000000 p168= 0.000000 p169= 0.000000 p170= 0.000000 p171= 0.000000 p172= 0.000000 p173= 0.000000 p174= 0.000000 p175= 0.000000 p176= 0.000000 p177= 0.000000 p178= 0.000000 p179= 0.000000 p180= 0.000000 p181= 0.000000 p182= 0.000000 p183= 0.000000 p184= 0.000000 p185= 0.000000 p186= 0.000000 p187= 0.000000 p188= 0.000000 p189= 0.000000 p190= 0.000000 p191= 0.000000 p192= 0.000000 p193= 0.000000 p194= 0.000000 p195= 0.000000 p196= 0.000000 p197= 0.000000 p198= 0.000000 p199= 0.000000 p200= 0.000000 p201= 0.000000 p202= 0.000000 p203= 0.000000 p204= 0.000000 p205= 0.000000 p206= 0.000000 p207= 0.000000 p208= 0.000000 p209= 0.000000 p210= 0.000000 p211= 0.000000 p212= 0.000000 p213= 0.000000 p214= 0.000000 p215= 0.000000 p216= 0.000000 p217= 0.000000 p218= 0.000000 p219= 0.000000 p220= 0.000000 p221= 0.000000 p222= 0.000000 p223= 0.000000 p224= 0.000000 p225= 0.000000 p226= 0.000000 p227= 0.000000 p228= 0.000000 p229= 0.000000 p230= 0.000000 p231= 0.000000 p232= 0.000000 p233= 0.000000 p234= 0.000000 p235= 0.000000 p236= 0.000000 p237= 0.000000 p238= 0.000000 p239= 0.000000 p240= 0.000000 p241= 0.000000 p242= 0.000000 p243= 0.000000 p244= 0.000000 p245= 0.000000 p246= 0.000000 p247= 0.000000 p248= 0.000000 p249= 0.000000 p250= 0.000000 p251= 0.000000 p252= 0.000000 p253= 0.000000 p254= 0.000000 p255= 0.000000 p256= 0.000000 p257= 0.000000 p258= 0.000000 p259= 0.000000 p260= 0.000000 p261= 0.000000 p262= 0.000000 p263= 0.000000 p264= 0.000000 p265= 0.000000 p266= 0.000000 p267= 0.000000 p268= 0.000000 p269= 0.000000 p270= 0.000000 p271= 0.000000 p272= 0.000000 p273= 0.000000 p274= 0.000000 p275= 0.000000 p276= 0.000000 p277= 0.000000 p278= 0.000000 p279= 0.000000 p280= 0.000000 p281= 0.000000 p282= 0.000000 p283= 0.000000 p284= 0.000000 p285= 0.000000 p286=

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