Scilab Manual for Probability Theory and Random Processes by Prof Shital Thakkar Others Dharmsinh Desai University[1]

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Experiment: 1

Write a program to find probability of tossing a coin and rolling a die through large no. of experimentation.

Scilab code Solution 1.1 Calculates probability of sum of tossing two dice

```
1  // Operating System : Windows XP or later,
2  // Scilab           : 5.3.3
3
4  //Program of Tossing two dice and observing
       Probability of sum of their front face.
5  //for e.g. Probability of sum of two dice = 2 is
       1/36 as there are 36 possibilities and sum = 2
       can// occur only one combination that is both
       face = 1
6  clc;
7  clear;
8  clf;
9  N = 10000;  // Number of times tossing of die
       performed
10 count = 0;  // Counter for counting number of times
```

```
   sum of die
for i = 1:N
    y1 = ceil(rand(1)*6); // output of die 1
    y2 = ceil(rand(1)*6); // output of die 2
    if((y1+y2) == 3)      // check for sum of front
       face of both die is == 3(change sum and)
        count = count + 1;//increment the count
           value when sum = 3 occurs
    end
    prob1(i) = count/i;      // no. of times sum of
       die = 3/total no. trials
end
plot(prob1)
xlabel('Number of Trials');
ylabel('Probability');
title('Probability of getting sum of dots on faces
   of a dice to be 3');


//Assignment : Program can be checked for other
   values of sum at line number 10.
```

Scilab code Solution 1.2 Finds probability of getting Head when a coin is tossed

```
// Operating System : Windows XP or later,
// Scilab           : 5.3.3


//This program find probability of getting Head when
    a coin is tossed.
//Probability = 1/2 = 0.5 as there are two possible
   outcomes in coin tossing experiment.
```

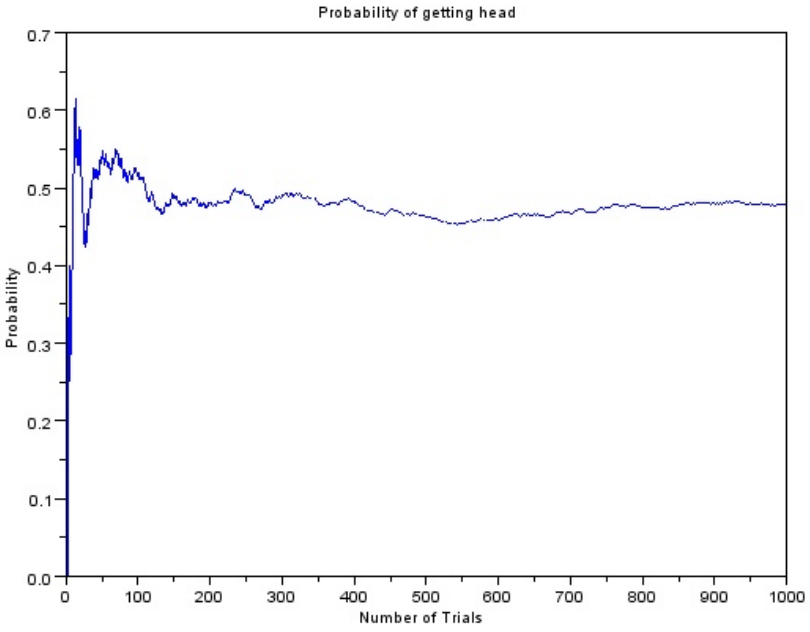

Figure 1.1: Finds probability of getting Head when a coin is tossed

```
clc;
clear all;
clf;
a1 = 1000;
count1 = 0;
for i = 1:a1
x = round(rand(1));
    //round: the elements to nearest integer
    //rand:returns a pseudorandom, scalar value
       drawn from a uniform
    //distribution on the unit interval.
    if(x==1)// HEAD- '1',condition that detects '
       HEAD' comes or not
        count1 = count1 + 1;//increment the count
           value when head occurs
    end
    p(i)= count1/i;//probability of head occuring at
        ith trail
end
plot(1:a1,p)
//plot the prob. at ith trail(plots discrete
   sequence)
xlabel('Number of Trials');
ylabel('Probability');
title('Probability of getting head');
//Assignment:
//1.   perform above experiment with n = 100,1000 .
//2.   Extend the above experiment to find
   probability of 3 heads in 4 coin tosses.
//    Match the result theoretically.
```

Experiment: 2

To generate Uniform, Gaussian and Exponential distributed data for given mean and variance.

Scilab code Solution 2.1 Generation of Uniform Data

```
1 //To generate Uniform, Gaussian and Exponential
    distributed data.
2 // Operating System : Windows XP or later,
3 // Scilab           : 5.3.3
4 //NOTE:EXECUTE ONE BY ONE SEGEMENT
5
6 //[1] Uniform Data Generation
7 clc;
8 clear all;
9 //b = input('higher limit of uniform r.v. b = ')//
    Enter higher limit of uniform r.v.
10 //a = input('lower limit of uniform r.v. a =')//
    Enter lower limit of uniform r.v.
```

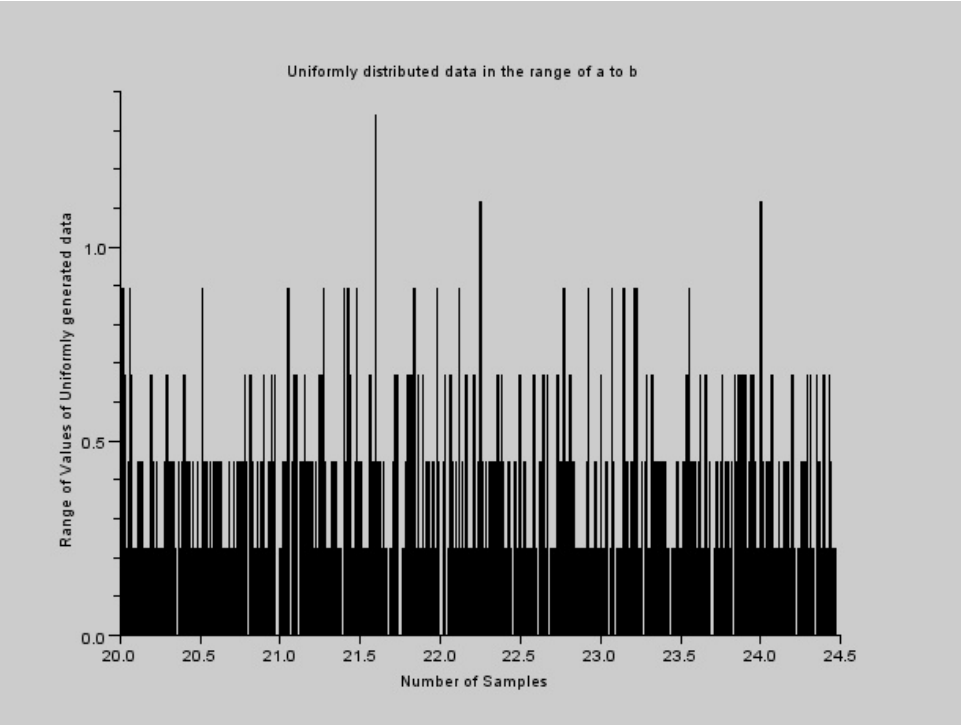

Figure 2.1: Generation of Uniform Data

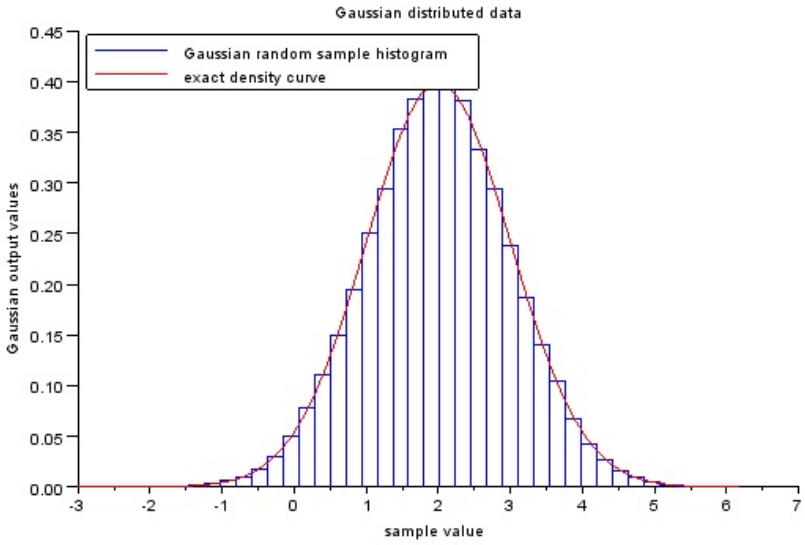

Figure 2.2: Gaussian Data Generation

```
11 clf();
12 b=4;//higher range of uniform data
13 a=2;//lower range of uniform data
14 x=a + (b-a).*rand(1,1000,'uniform'); //uniform data
      generation of length 100
15 histplot(1000,x)//histogram of generated data
16 xlabel('Number of Samples');
17 ylabel('Range of Values of Uniformly generated data'
      );
18 title('Uniformly distributed data in the range of a
      to b');
```

Scilab code Solution 2.2 Gaussian Data Generation

```
1 //To generate Uniform, Gaussian and Exponential
    distributed data.
2 // Operating System : Windows XP or later,
3 // Scilab           : 5.3.3
4
5 //[2] Expoenential data generation & Mean and
    Variance Calcultaion of Exponential distributed
    data.
6 clc;
7 clear all;
8 clf();
9 //(i) Exponential data generation
10 lambda = 2;//or lambda = input('enter lemda value
    for exponential r.v.')//lemda of exponential data
    ;
11 X = grand(10000,1,"exp", 1/lambda);
12 Xmax = max(X);
13 histplot(40, X, style=2)
14 x = linspace(0,max(Xmax),100)';
15 plot2d(x,lambda*exp(-lambda*x),strf="000",style=5)
16 legend(["exponential random sample histogram" "exact
     density curve"]);
17 xlabel('sample value');
18 ylabel('Exponential output values');
19 title('Exponential distributed data');
```

Scilab code Solution 2.3 Exponential Data Generation

```
1 //To generate Uniform, Gaussian and Exponential
    distributed data.
2 // Operating System : Windows XP or later,
3 // Scilab           : 5.3.3
4
```

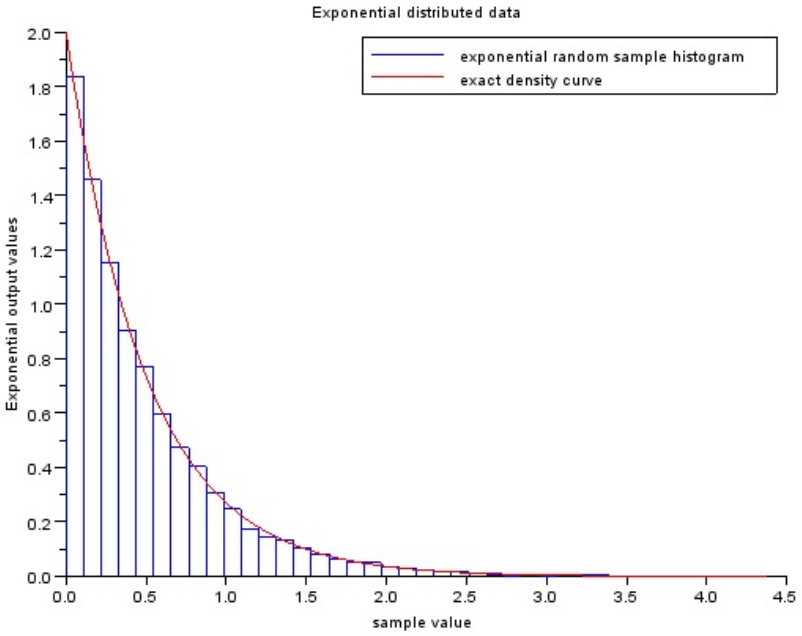

Figure 2.3: Exponential Data Generation

```
5  //[3]Gaussian data generation
6  //Gaussian data generation
7  clc;
8  clear all;
9  clf();
10 //m = input('enter mean value for Gaussian r.v.')
11 //vari = input('enter mean value for Gaussian r.v.')
12 m = 2;//mean value of gaussian data
13 sd = 1;//standard deviation
14 vari = sd^2;
15 X = grand(100000,1,"nor", m,sd);
16 Xmax = max(X);
17 clf()
18 histplot(40, X, style=2)
19 x = linspace(-10,max(Xmax),100)';
20 plot2d(x,(1/(sqrt(2*%pi*vari)))*exp(-0.5*(x-m).^2/
      vari),strf="000",style=5)
21 xlabel('sample value');
22 ylabel('Gaussian output values');
23 title('Gaussian distributed data');
24 legend(["Gaussian random sample histogram" "exact
      density curve"],2);
```

Experiment: 3

Write a program to generate M trials of a random experiment having specific number of outcomes with specified probabilities.

Scilab code Solution 3.1 Random experiment with outputs in specific range

```
1 // Operating System : Windows XP or later,
2 // Scilab           : 5.3.3
3
4 //Write a program to generate M trials of a random
     experiment having specific
5 //number of outcomes with specified probabilities.
6 //here No. of trials = 1000,no. outcomes(rv) = 3
     with specied probability entered by user
7 clc;
8 clear all;
9 rand('seed')//check
10 M = 1000; //Number of trials of random experiment
11 outcomes = 3;  //Possible number of outcomes of
```

```
    random experiment
for i = 1:outcomes-1
    r(i) = input('enter upper range of probability
       of r.v. (values in the 0<r<1) :')//enter
       values in the 0<r<1
    if r(i)>1 then
        error('Enter values in the range 0<r<1')
    end
end
x = zeros(M,1);
for i = 1:M
    u = rand(1,1);//random outcome
    if u <= r(1) then
        x(i,1)=1;//assign rv value = 1 if u<=r(1)
    elseif u > r(1) & u<= r(2)
        x(i,1)=2;//second rv value
    else
        x(i,1)=3; //third rv value
    end
end
count1=0;count2=0;count3=0;
for i=1:1000
    if x(i,1)==1 then
        count1 = count1 + 1;
    elseif x(i,1)== 2
        count2 = count2 + 1;
    else
        count3 = count3 + 1;
    end
end
estP1 = count1/M;disp(estP1)//estimated probability
    of generated random variable
estP2 = count2/M;disp(estP2)//estimated probability
    of generated random variable
estP3 = count3/M;disp(estP3)//estimated probability
    of generated random variable

//Assignment:
```

```
44 //1. Extend this program for 4 number of random
       variable
45 //2. Extend this program for more number of trials.
       i.e. M = 5000,10000 etc.
```

Experiment: 4

To find estimated and true mean of Uniform, Gaussian and Exponential distributed data.

Scilab code Solution 4.1 Comaparison of True and estimated statics of Uniform Data

```
1  // Operating System : Windows XP or later,
2  // Scilab           : 5.3.3
3  //here we generate uniformly distributed data
       compare its statistics with calculated using
       equation.
4
5
6
7  //[1] Mean and Variance Calcultaion of Uniformly
       distributed data
8
9  clc;
10 clear all;
11 b=4;//higher range of uniform data
12 a=2;//lower range of uniform data
13 x=a + (b-a).*rand(1,1000); //Uniform data generation
```

```
    using function
Uni_true_mean=mean(x)
mprintf('Uniform True Mean = %f',Uni_true_mean)
Uni_true_var = variance(x)
mprintf('\n Uniform True Mean = %f',Uni_true_var)
px = 1/(b-a)//pdf calcultaion of uniform r.v.
m_uniform=integrate('x*px','x',a,b)//mean
   calcultaion of uniform r.v.
fsq_uniform=integrate('(x^2)*px','x',a,b)//mean
   square value of uniform r.v.
var_uniform = fsq_uniform - (m_uniform).^2//variance
    of uniform r.v.

mprintf('\n Uniform Calculated Mean = %f',m_uniform)
mprintf('\n Uniform Calculated Variance = %f',
   var_uniform)
```

Scilab code Solution 4.2 Comaparison of True and estimated statics of Gaussian Data

```
// Operating System : Windows XP or later,
// Scilab           : 5.3.3

//here we generate Gaussian distributed data compare
    its statistics with calculated using equation.

//[3] Mean & Variance calculation of Gaussian Data

clc;
clear all;
m = 2;//mean value of gaussian data
sd = 1;//standard deviation
vari = sd^2;
X = grand(10000,1,"nor", m,sd);//gaussian data
   generation using function
```

```
14 Gaus_true_mean=mean(X)
15 mprintf('Gaussian True Mean = %f',Gaus_true_mean)
16 Gaus_true_var=variance(X)
17 mprintf('\n Gaussian True Variance = %f',
      Gaus_true_var)
18
19 //Mean and variance calcultaion using formula
20 gs_mean=integrate('x*(1/sqrt(2*%pi*vari)*exp(-(x-m)
      ^2/(2*vari)))','x',0,100)
21 gs_fsq=integrate('(x^2)*(1/sqrt(2*%pi*vari)*exp(-(x-
      m)^2/(2*vari)))','x',0,100);
22 gs_var = gs_fsq - gs_mean.^2;
23 mprintf('\n Gaussian Calculated Mean = %f',gs_mean)
24 mprintf('\n Gaussian Calculated Variance = %f',
      gs_var)
```

Scilab code Solution 4.3 Comaparison of True and estimated statics of Exponential Data

```
1 // Operating System : Windows XP or later,
2 // Scilab           : 5.3.3
3
4 //here we generate Exponentially distributed data
     compare its statistics with calculated using
     equation.
5
6 //[2] Mean and Variance Calculation of Exponential
     data
7 clc;
8 clear all;
9 lambda = 2;//or lambda = input('enter lemda value
     for exponential r.v.')//lemda of exponential data
     ;
10 X = grand(1000,1,"exp", 1/lambda);//Exponential data
     generation using function
```

```
11 Expo_true_mean=mean(X)
12 mprintf('Exponential True Mean = %f',Expo_true_mean)
13 Expo_true_var=variance(X)
14 mprintf('\n Exponential True Variance = %f',
      Expo_true_var)
15
16 //Mean and variance calcultaion using formula
17 ex_mean=integrate('x*(lambda*exp(-lambda*x))','x'
      ,0,100)
18 ex_fsq=integrate('(x^2)*(lambda*exp(-lambda*x))','x'
      ,0,100);
19 ex_var = ex_fsq - ex_mean.^2
20 mprintf('\n Exponential Calculated Mean = %f',
      ex_mean)
21 mprintf('\n Exponential Calculated Variance = %f',
      ex_var)
```

Experiment: 5

To find density and distribution function of a function of random variable Y = 2X + 1. where X is gaussian R.V.

Scilab code Solution 5.1 Density and Distribution plot generation for one function of Random Variable

```
1 // Operating System : Windows XP or later,
2 // Scilab           : 5.3.3
3
4 //To find density(pdf) and distribution(cdf)
     function of a function of random variable
5 //Y = 2X + 1(having form Y = aX + b). where X is
     gaussian R.V.
6
7 clc;
8 clear all;
9 clf();
10 mean_x = 1;//mean value of gaussian data
```

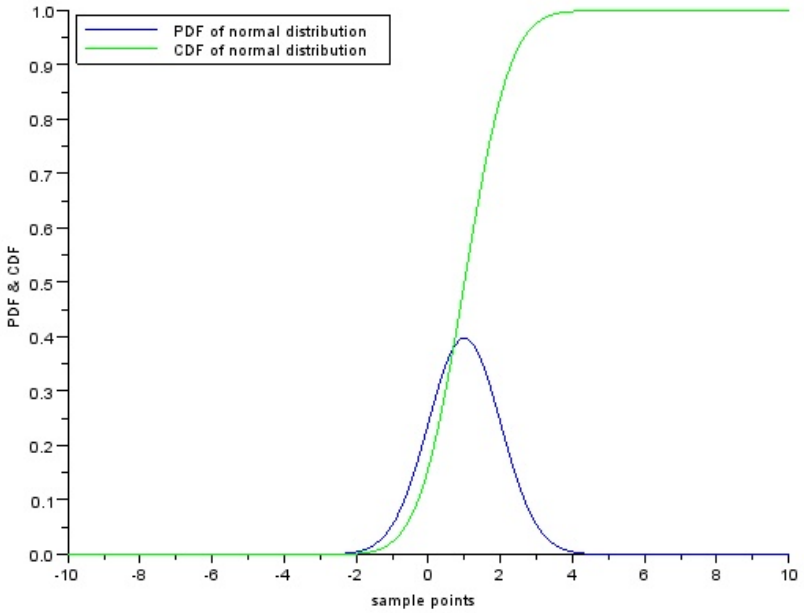

Figure 5.1: Density and Distribution plot generation for one function of Random Variable

```
11 sd_x = 1;//standard deviation
12 vari_x = sd_x.^2;
13 lgd = [];
14 //PDF and CDF of Gaussian Random Variable X
15 x = linspace(-10,10,100);
16 plot2d(x,((1/(sqrt(2*%pi*vari_x)))*exp(-0.5*(x-
      mean_x).^2/vari_x)),2);//plots pdf of X
17 set(gca(),"auto_clear","off")
18 plot2d(x,cdfnor("PQ",x,mean_x*ones(x),sd_x*ones(x))
      ,3);//cdf of gaussian RV X
19 set(gca(),"auto_clear","on")
20 xlabel('sample points');
21 ylabel('PDF & CDF');
22 //title('density and distribution function for
      Gaussian function');
23 legend(['PDF of normal distribution';'CDF of normal
      distribution'],2);
24
25 //PDF and CDF of Y = aX + b where a = 2, b = 1
26 a = 2;
27 b = 1;
28 y = a*x+b;//Function of One Random Variable
29 mean_y=a*mean_x+b;
30 vari_y=(a*sd_x).^2;
31 figure(2,"BackgroundColor",[1,1,1]);
32 plot2d(y,((1/(sqrt(2*%pi*vari_y*a.^2)))*exp(-0.5*(y-
      mean_y).^2/vari_y)),2);//pdf of Y
33 set(gca(),"auto_clear","off")
34 plot2d(x,cdfnor("PQ",y,(a*mean_x+b)*ones(x),(a*sd_x)
      *ones(x)),3);//cdf of y
35 set(gca(),"auto_clear","on")
36 xlabel('sample points');
37 ylabel('PDF & CDF of Y = 2X + 1');
38 legend(['PDF of Y = 2X + 1';'CDF of Y = 2X + 1'],2);
39
40
41 //Assignment :
42 //1. Perform the operation for function Y = 5X + 1.
```

```
43 //2. Generate pdf and cdf of nonlinear function
      between Y and X.
```

Experiment: 6

Estimate the mean and variance of Y = 2X + 1, where X is a gaussian random variable.

Scilab code Solution 6.1 Statistics of Function of one random variable

```
1  // Operating System : Windows XP or later,
2  // Scilab           : 5.3.3
3
4  //True and Estimated value of mean and variance of
       function of one random
5  //variable having form of Y = aX +b.
6  clc;
7  clear all;
8  rand('seed',getdate('s'))
9  m = 0;//mean of random variable x
10 vari = 1;//variance of random variable x
11 m_est = 0;
12 var_est = 0;
13 for i = 1:1000
14     y(i,1)= 1 +2*rand(1,1,"normal");// Y = 2X + 1
```

```
        where x is gaussian data
15      m_est = m_est + ((1/1000)*y(i));//estimation by
        averaging
16      var_est = var_est +((1/1000)*(y(i)-m_est)^2);
17  end
18  printf('Estimated mean of Y(=2X + 1) is: Est_mean=%f
    ',m_est)
19  printf('\n Estimated variance of Y) is: Est_variance
    =%f',var_est)
20  //Calculation of true mean of Y
21  y_mean=integrate('(2*x+1)*(1/sqrt(2*%pi*vari)*exp(-(
    x-m)^2/(2*vari)))','x',-100,100);
22  printf('\n True mean of Y(=2X + 1) is: True_mean=%f'
    ,y_mean)
23  //Calculation of true variance of Y
24  //for a function like Y = aX + b the variance of Y
    is a^2*Variance of X.
25  gs_mean=integrate('x*(1/sqrt(2*%pi*vari)*exp(-(x-m)
    ^2/(2*vari)))','x',-50,100);
26  gs_fsq=integrate('((x^2)*(1/sqrt(2*%pi*vari)*exp(-(x
    -m)^2/(2*vari))))','x',-50,100);
27  gs_var = gs_fsq - (gs_mean).^2;
28  var_y = 2^2*gs_var;//here a = 2
29  printf('\n True variance of Y(=2X + 1) is:
    True_variance=%f',var_y)
30
31  //Expectation of Y is E(Y)=E(2X+1)=2E(X)+1. That's
    why answer is 1.
32  //True variance of Y in this format is equal to a^2*
    variance of X.
33  //Assignment:
34  //1. Assume X is uniform random variable between a
    to b. find mean and variance.
```

Experiment: 7

Plot Joint density and distribution function of sum of two Gaussian random variable (Z = X + Y).

Scilab code Solution 7.1 Joint Density and Distribution of Function of two random varible

```
1 // Operating System : Windows XP or later ,
2 // Scilab           : 5.3.3
3
4
5 //Plot Joint density and distribution function of
     sum of two Gaussian random variable (Z = X + Y).
6 clc;
7 clear all;
8 clf();
9
```

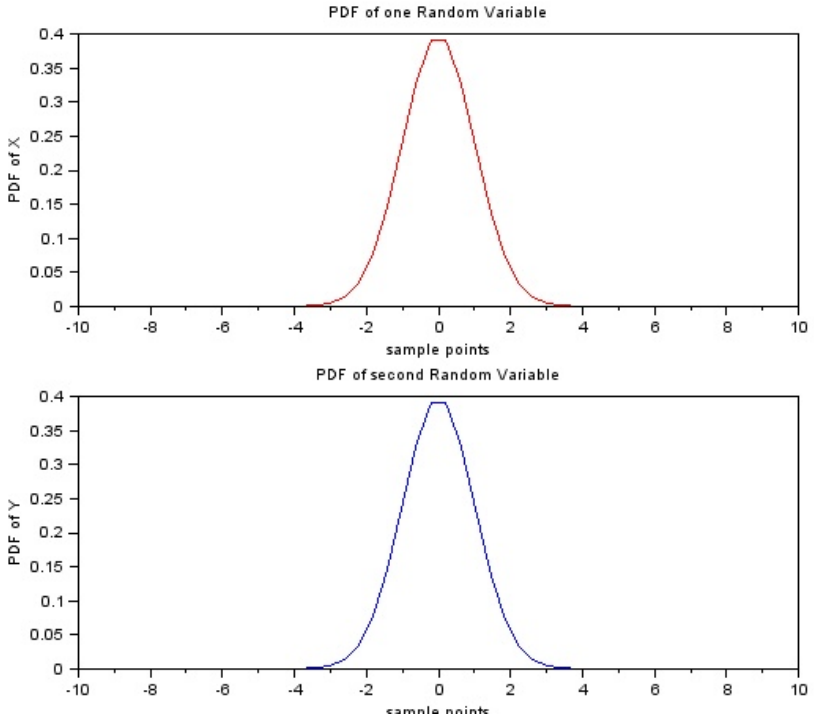

Figure 7.1: Joint Density and Distribution of Function of two random varible

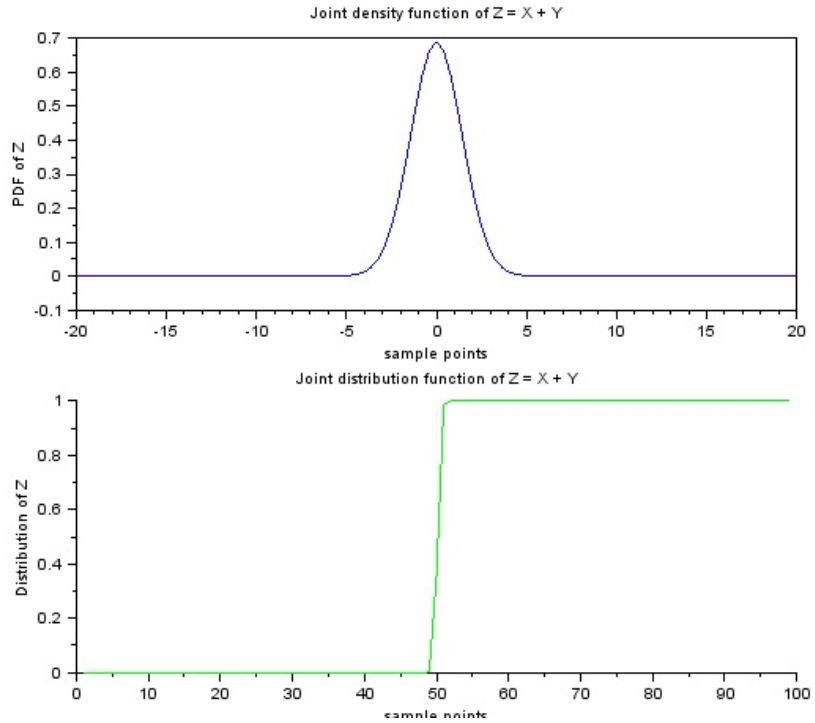

Figure 7.2: Joint Density and Distribution of Function of two random varible

```
10 //PDF of Gaussian Random Variable X
11 mean_x = 0;//mean of first gaussian RV
12 sd_x = 1;//standard deviation of first gausssian RV
13 vari_x = sd_x.^2;
14
15 x = linspace(-10,10,50);//generating linearly spaced
       data as Random output
16 X = ((1/(sqrt(2*%pi*vari_x)))*exp(-0.5.*(x-mean_x)
     .^2/vari_x));//finding gaussian pdf of above data
17 subplot(2,1,1);
18 plot(x,X,'r')
19 xlabel('sample points');
20 ylabel('PDF of X');
21 title('PDF of one Random Variable')
22
23
24 //PDF of Gaussian Random Variable Y
25 mean_y = 0;
26 sd_y = 1;
27 vari_y = sd_y.^2;
28
29 y = linspace(-10,10,50);
30 Y = ((1/(sqrt(2*%pi*vari_y)))*exp(-0.5.*(y-mean_y)
     .^2/vari_y));
31 subplot(2,1,2);
32 plot(y,Y,'b')
33 xlabel('sample points');
34 ylabel('PDF of Y');
35 title('PDF of second Random Variable')
36
37 // Joint pdf of sum of random variable X & Y
38 // When two IID random variable are summen up, their
       Joint PDF is convolution between individual pdfs
       of Random variables
39 z = convol(X,Y);
40 figure(2,"BackgroundColor",[1,1,1]);
41 subplot(2,1,1);plot(linspace(-20,20,99),z)//Joint
     PDF
```

```
42 xlabel('sample points');
43 ylabel('PDF of Z');
44 title('Joint density function of Z = X + Y')
45 P = cdfnor("PQ",linspace(-20,20,99),mean(z)*ones(z),
      sqrt(variance(z))*ones(z));
46 set(gca(),"auto_clear","off")
47 subplot(2,1,2);plot2d(1:length(P),P,3);
48 xlabel('sample points');
49 ylabel('Distribution of Z');
50 title('Joint distribution function of Z = X + Y')
51 set(gca(),"auto_clear","on")
52 //Assignment:
53 //Change mean and variance of individual random
      variable X and Y and observe output
```

Experiment: 8

Estimate the mean and variance of a R.V. Z = X+Y. Where X and Y are also random variables.

Scilab code Solution 8.1 Estimation of mean and variance of sum of two random variable

```
1 // Operating System : Windows XP or later ,
2 // Scilab           : 5.3.3
3
4 //Concept :Estimation of mean and variance of sum of
      two random variable Z = X + Y, where X and Y are
      random variable.
5 // Above concept is explained with example as
     follows.
6 //Example: A large circular dartboard is set up with
      a "bullseye" at the center of the circle ,which
     is at the coordinate(0,0). A dart is thrown at
     the center but lands at (X,Y) are two different
     Gaussian random variables. What is average
     distance of the dart from the bullseye? What is
```

```
    variance of data?
7 //Distance from center is given as sqrt(X^2+Y^2)
8
9 clc;
10 clear all;
11 rand('seed',0)//setting seed of random generator to
    zero
12 m_est = 0;
13 for i = 1:1000
14     R(i,1)=sqrt(rand(1,1,'normal')^2+rand(1,1,'
        normal')^2);//calculation of distance from
        center
15     m_est=m_est+(1/1000)*R(i);//estimation of mean
        from data
16 end
17 m_est
18 mprintf('Mean of Sum of Two Random variable that is
    Mean of Z = %f',m_est)
19 v_est = variance(R)//variance calculation
20 mprintf('\n Variance of Sum of Two Random variable
    that is Mean of Z = %f',v_est)
```

Experiment: 9

Simulation of Central Limit Theorem.

Scilab code Solution 9.1 Summation of two random variable leads to Gaussian density function

```
1 // Operating System : Windows XP or later,
2 // Scilab           : 5.3.3
3
4
5 //Simulation of Central Limit Theorem.
6 //(Which says that if we keep on adding independant
     Random Variables then it density function
7 //approches to gaussian distribution)
8 //here two uniform RVs are added.
9
10 clc;
11 clear all;
12 clf();
13 n = 0:0.01:1;
14 x = zeros(length(n),1);
15 i = 1:50;//length of Uniform rv 1
```

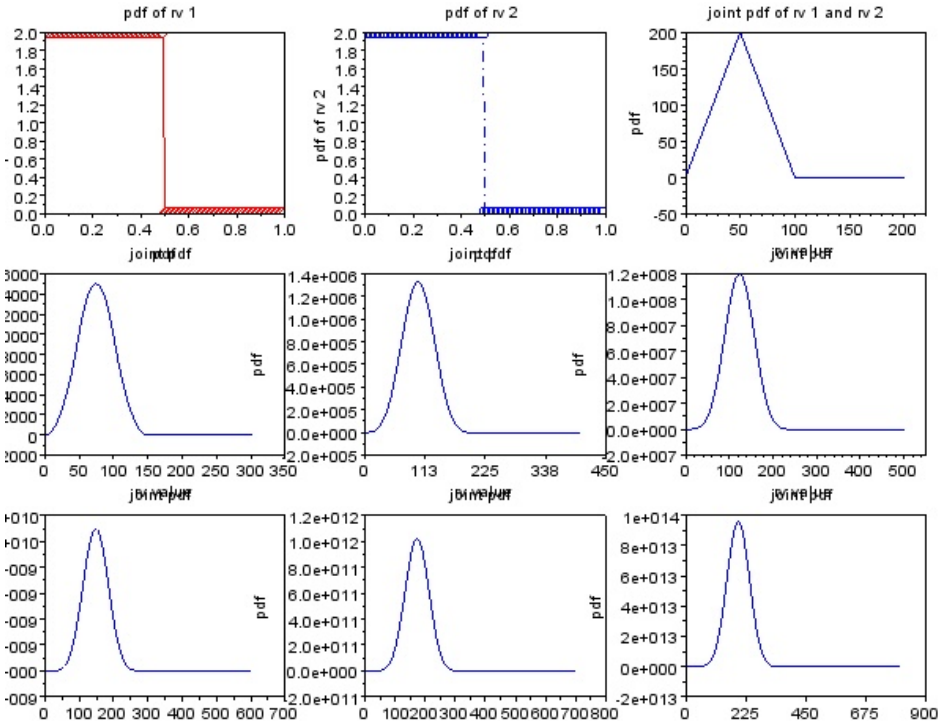

Figure 9.1: Summation of two random variable leads to Gaussian density function

```
16 x(i)= 2;
17 subplot(3,3,1);
18 plot(n,x,'r-d')
19 xlabel('pdf');ylabel('pdf of rv 1')
20 title('pdf of rv 1 ');
21
22 y = zeros(length(n),1);
23 j = 1:50;
24 y(j)= 1*2;//length of Uniform rv 2
25 subplot(3,3,2);
26 plot(n,y,'bo-.')
27 xlabel('pdf');
28 ylabel('pdf of rv 2')
29 title('pdf of rv 2');
30
31 z1 = convol(x,y);
32 subplot(3,3,3)
33 //When two independent RVs are added their joint
     density is convolution of marginal density
34 plot(z1)
35 xlabel('rv value');
36 ylabel('pdf')
37 title('joint pdf of rv 1 and rv 2');
38
39 for i = 4:9 // adding rv 9 times
40     subplot(3,3,i)
41     z1 = convol(z1,y);
42     plot(z1)
43     xlabel('rv value');
44     ylabel('pdf')
45 title('joint pdf');
46 end
```