# MA226 : Monte-Carlo Simulation
# Generation of Multivariate Random Numbers
Assignment 9

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# 1 Problem 1 and 2

We have to generate Bivariate Random Numbers for the given parameters.

## 1.1 Source code of the solution

```
library(MASS)

n<-10000
a_arr<-c(-0.25,0,0.25)
mu<-matrix(c(5,8),nrow=2,ncol=1)

for(a in 1:length(a_arr)){

        cat("Calculation for c = ",a_arr[a],"\n")

        sigma<-matrix(c(1,2*a_arr[a],2*a_arr[a],4),nrow=2,ncol=2)

        sigma_root<-matrix(c(sqrt(sigma[1,1]),0,
                        a_arr[a]*sqrt(sigma[2,2]),
                        sqrt(sigma[2,2]*(1-a_arr[a]*a_arr[a]))),
                        nrow=2,ncol=2,byrow=TRUE)

        sample1<-vector(length=n)
        sample2<-vector(length=n)

        for(i in 1:n){
                normal_mat<-matrix(c(rnorm(1),rnorm(1)),nrow=2,ncol=1,byrow=TRUE)

                mat<-mu+sigma_root %*% normal_mat

                sample1[i]<-mat[1,1]
                sample2[i]<-mat[2,1]
        }

        mean1<-mean(sample1)
        mean2<-mean(sample2)
        var1<-var(sample1)
        var2<-var(sample2)
        cov_final<-cov(sample1,sample2)
        cor_final<-cor(sample1,sample2)

        cat("Mean vector : [",mean1," , ",mean2,"]\n")
        cat("Cov Matrix : [",var1," , ",cov_final,"]\n")
        cat("             [",cov_final," , ",var2,"]\n")
        cat("Correlation : ",cor_final,"\n")

        png(paste("cdf_sample1_",toString(a),".png"))
        plot(ecdf(rnorm(n,mean=mu[1,1],sd=sqrt(sigma[1,1]))),col='cyan')
        par(new=TRUE)
        plot(ecdf(sample1),col='red')

        png(paste("cdf_sample2_",toString(a),".png"))
```

```
        plot(ecdf(rnorm(n,mean=mu[2,1],sd=sqrt(sigma[2,2]))),col='cyan')
        par(new=TRUE)
        plot(ecdf(sample2),col='red')

        z<-kde2d(sample1,sample2)
        png(paste("contour_plot_",toString(a),".png"))
        contour(z)
        dev.off()
}
```

### 1.1.1 Plots

In the following plots, red line represents Emperical Distribution while blue line represents the actual Distribution.

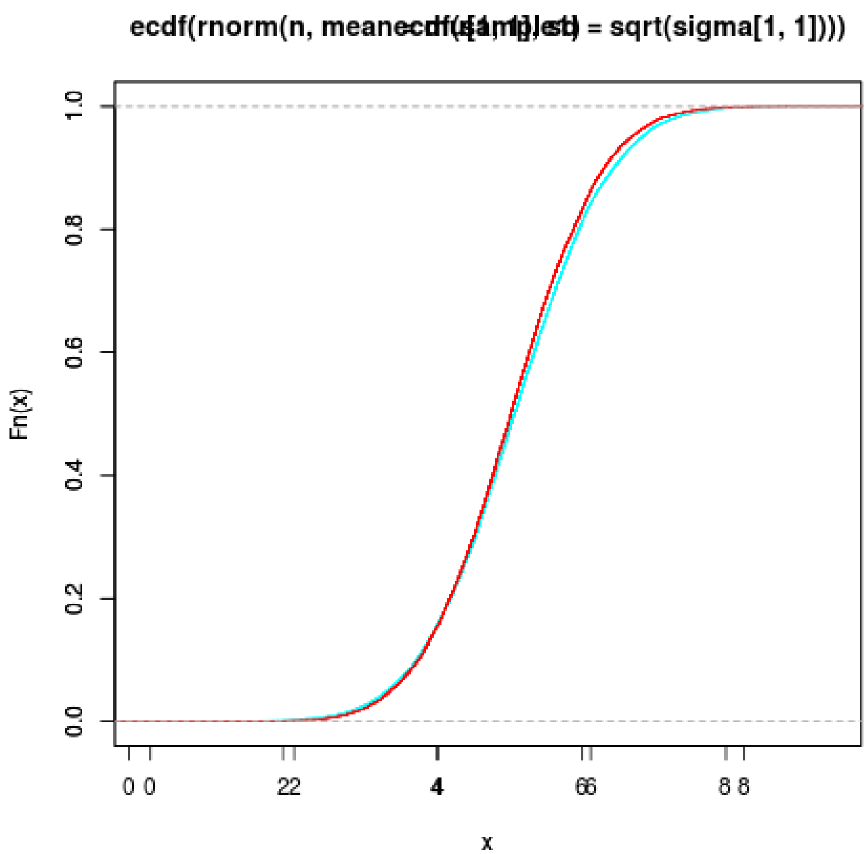


Abbildung 1: Cumulative Distribution Plot for Sample 1 when a=-0.25

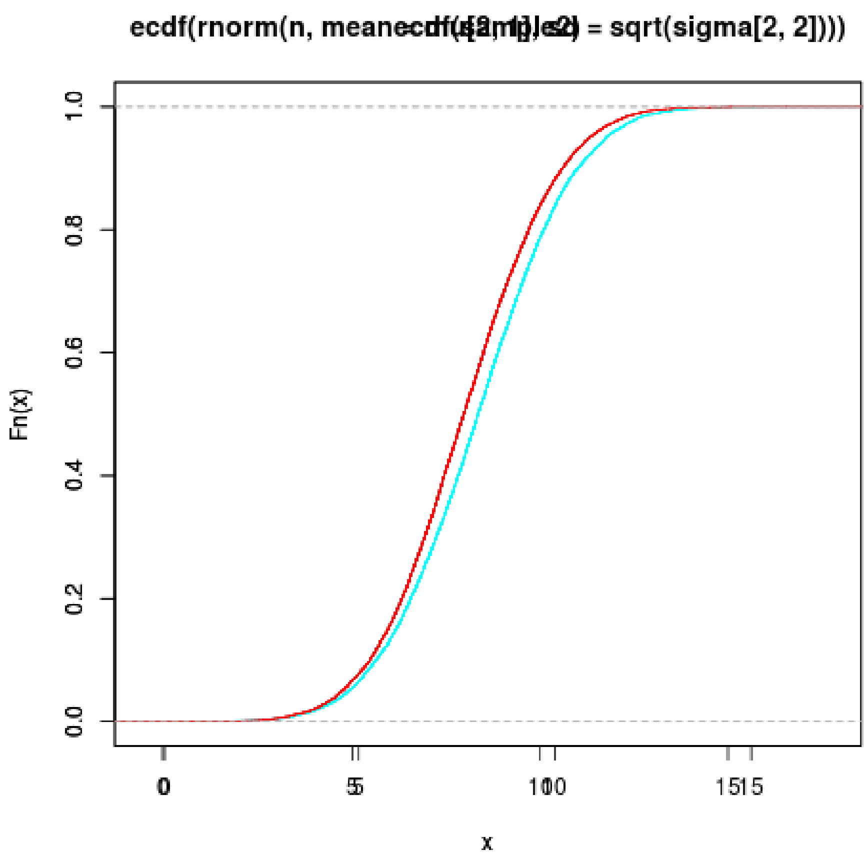


Abbildung 2: Cumulative Distribution Plot for Sample 2 when a=-0.25

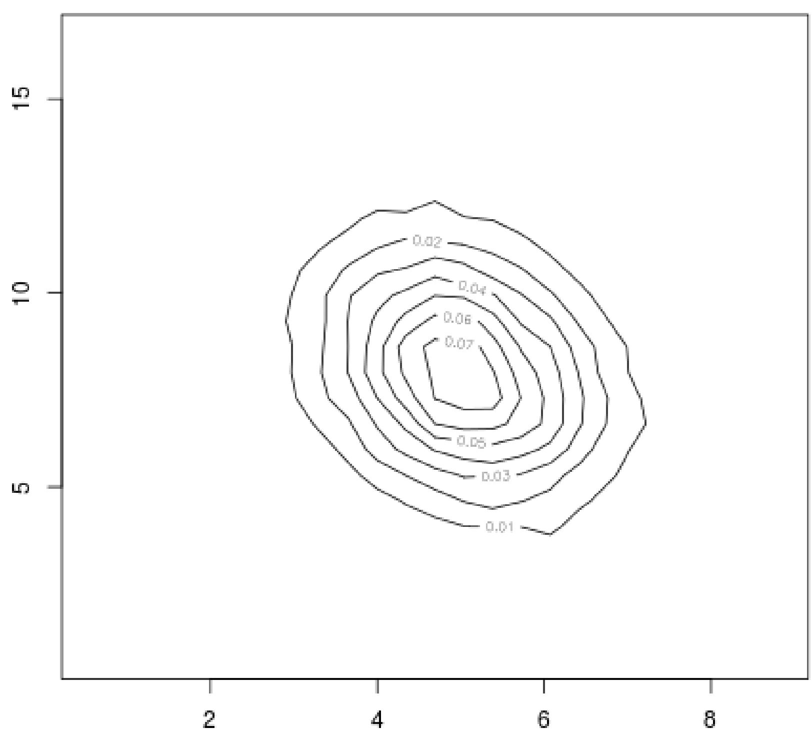


Abbildung 3: Contour Plots a=-0.25

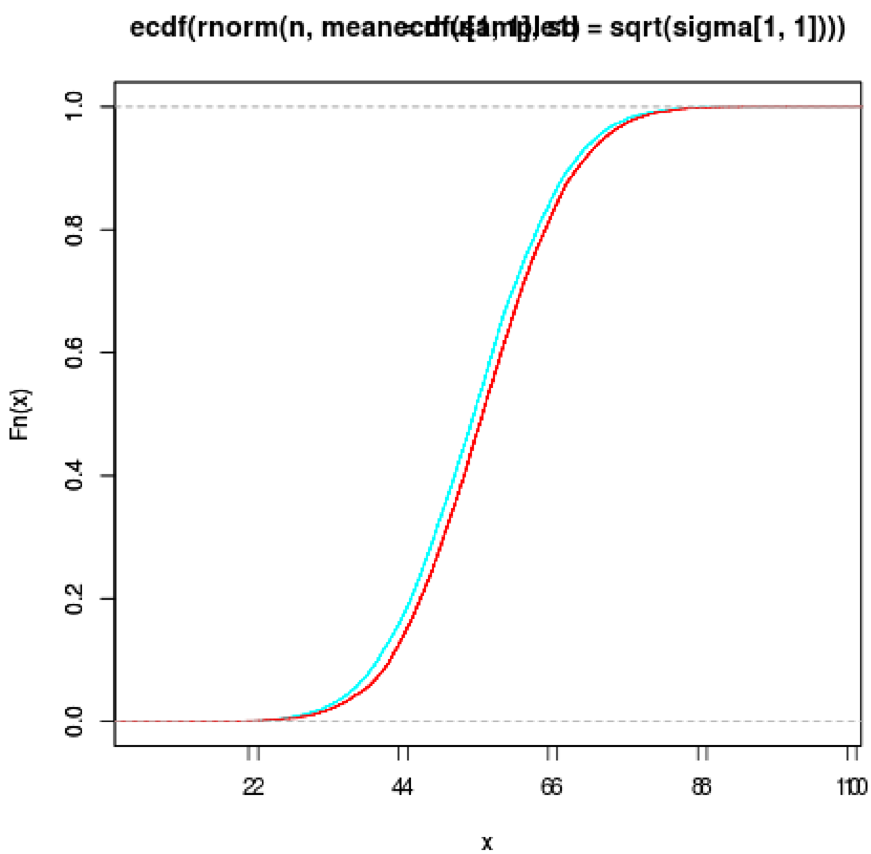


Abbildung 4: Cumulative Distribution Plot for Sample 1 when a=0

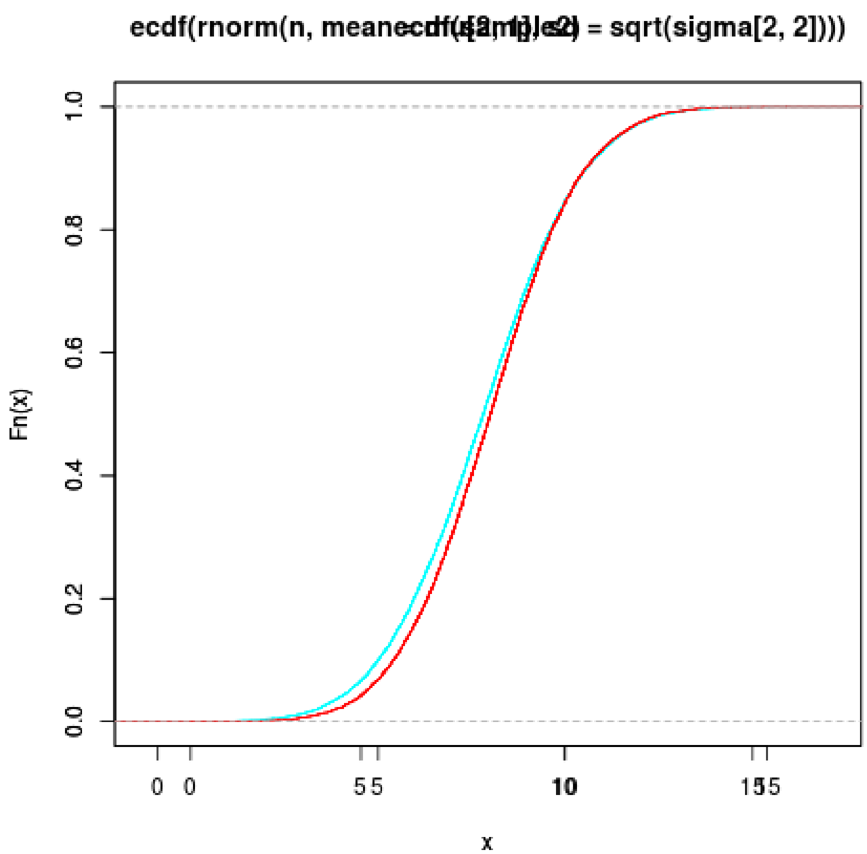


Abbildung 5: Cumulative Distribution Plot for Sample 2 when a=0

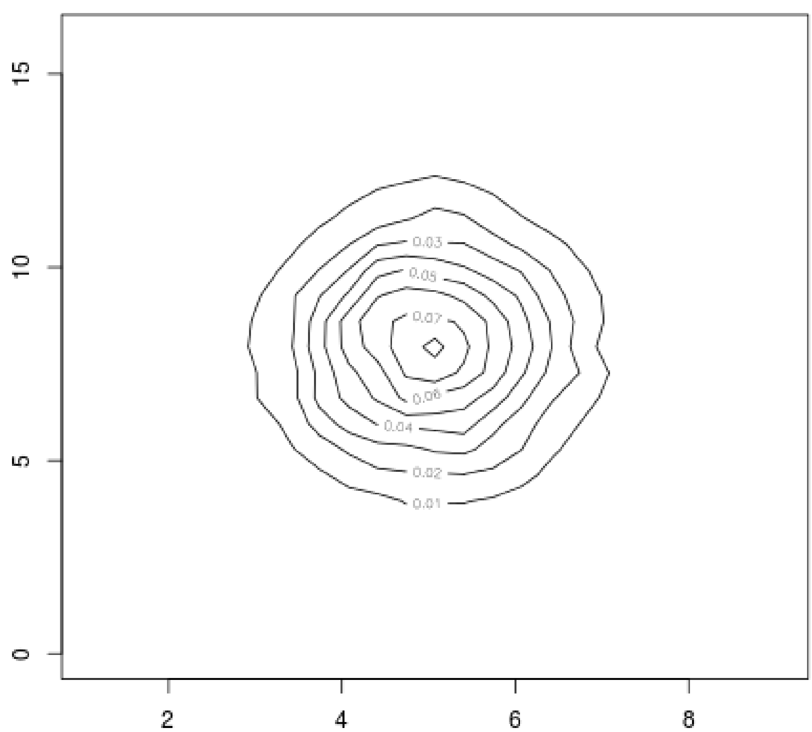


Abbildung 6: Contour Plots a=0

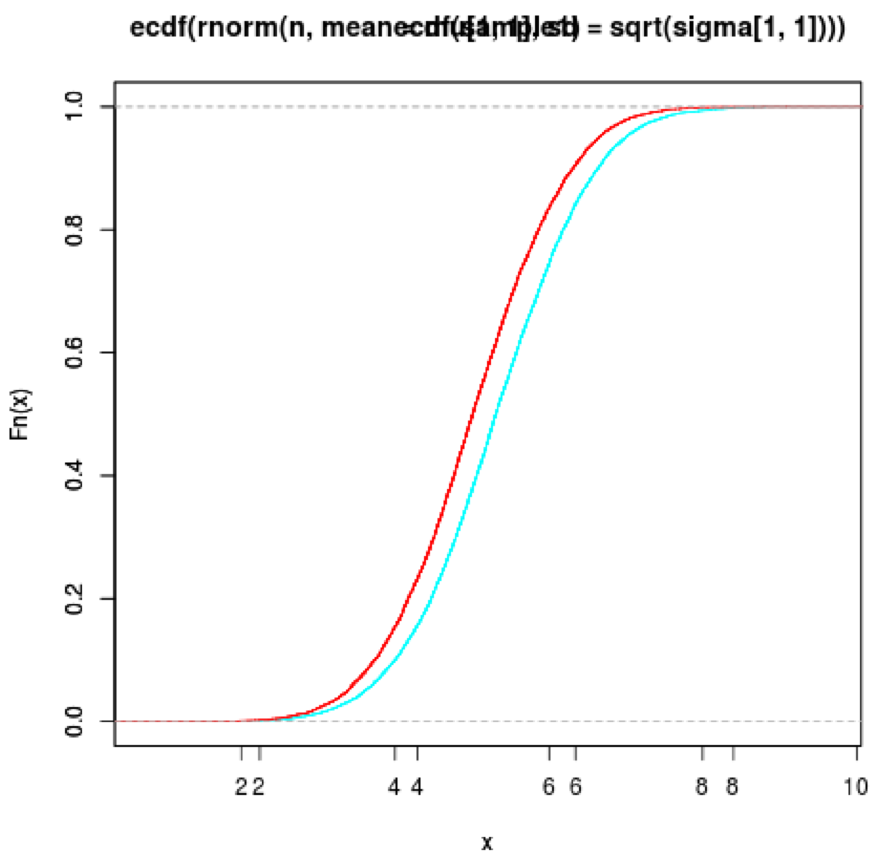


Abbildung 7: Cumulative Distribution Plot for Sample 1 when a=0.25

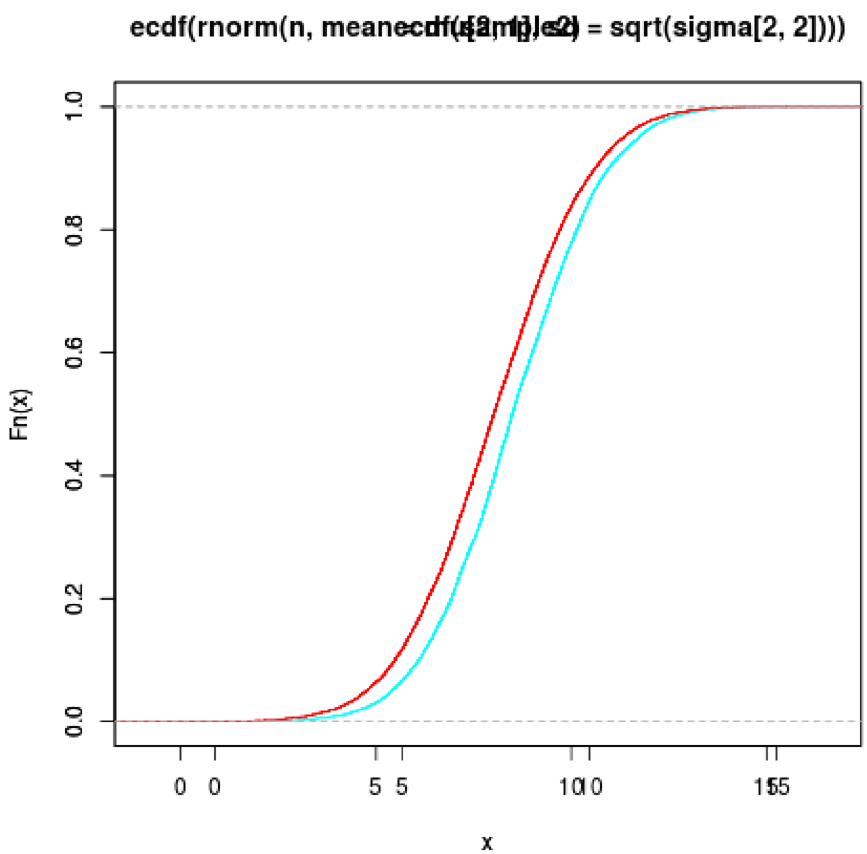


Abbildung 8: Cumulative Distribution Plot for Sample 2 when a=0.25

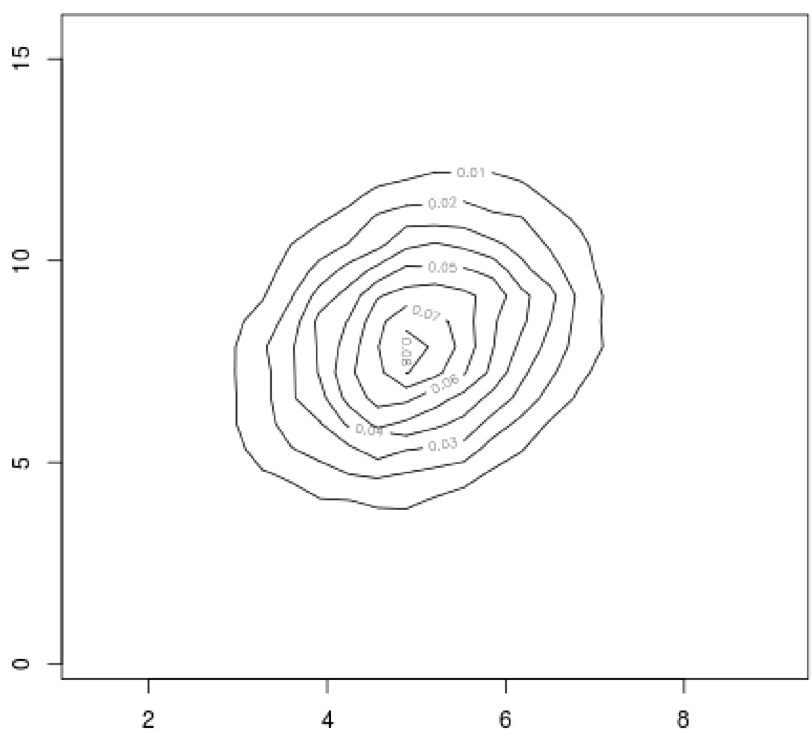


Abbildung 9: Contour Plots a=0.25

## 1.2 Observation

Calculation for a = -0.25
Correlation : -0.2593595

Calculation for a = 0
Correlation : -0.008781629

Calculation for a = 0.25
Correlation : 0.2582313

## 2 Problem 3

We have to generate Bivariate Normal Distribution using Conditioning which has same Parameters as problem before.

### 2.1 Source code of the solution

```
n<-10000
a<-c(-0.25,0,0.25)
sigma1<-1
sigma2<-2
mu1<-5
mu2<-8

for(i in 1:length(a)){

        cat("Calculatiog for a = ",a[i],"\n")

        u1<-rnorm(n)
        u2<-rnorm(n)

        x1<-mu1+sigma1*u1
        x2<-mu2+ a[i]*sigma2*(x1-mu1)/sigma1 +
                sqrt((1-a[i]*a[i])*sigma2*sigma2)*u2

        mean1<-mean(x1)
        mean2<-mean(x2)

        var1<-var(x1)
        var2<-var(x2)
        cor_final<-cor(x1,x2)
        cov_final<-cov(x1,x2)

        cat("Mean vector : [",mean1," , ",mean2,"]\n")
        cat("Cov Matrix : [",var1," , ",cov_final,"]\n")
        cat("              [",cov_final," , ",var2,"]\n")
        cat("Correlation : ",cor_final,"\n")

}
```

## 2.2 Observation

Calculatiog for a = -0.25
Mean vector : [ 5.013493 , 8.019835 ]
Correlation : -0.2459039

Calculatiog for a = 0
Mean vector : [ 4.99696 , 7.973594 ]
Correlation : -0.008732466

Calculatiog for a = 0.25
Mean vector : [ 4.999652 , 8.016126 ]
Correlation : 0.2522113