Applied Multivarate Analysis lab 4

1 Multivariate Normal

1.1 a function for computing the bivariate normal density

```
> # Import data from a excel file with .csv which separted by comma
> dbinorm<-function(x,mu,sigma)
+  {det<-sigma[1,1]*sigma[2,2]-sigma[1,2]*sigma[2,1]
+  a<-t(x-mu) %*% solve(sigma) %*% (x-mu)
+  exp(-a/2)/(sqrt(det)*2*pi)
+ }
> dbinorm

function(x,mu,sigma)
 {det<-sigma[1,1]*sigma[2,2]-sigma[1,2]*sigma[2,1]
 a<-t(x-mu) %*% solve(sigma) %*% (x-mu)
 exp(-a/2)/(sqrt(det)*2*pi)
}
```

1.2 create a zero mean vector and an identity variance matrix

```
> mu<-c(0,0)
> mu

[1] 0 0

> sigma<-matrix(c(1,0,0,1),ncol=2)  # ncol = # of columns
> sigma

     [,1] [,2]
[1,]    1    0
[2,]    0    1
```

1.3 create the range of values for which we wish to plot the density

```
> x<-seq(-3,3,length=20)  #  Creates a vector of evenly spaced numbers.  Length-number of va
> y<-seq(-3,3,length=20)
> y

 [1] -3.0000000 -2.6842105 -2.3684211 -2.0526316 -1.7368421 -1.4210526
 [7] -1.1052632 -0.7894737 -0.4736842 -0.1578947  0.1578947  0.4736842
[13]  0.7894737  1.1052632  1.4210526  1.7368421  2.0526316  2.3684211
[19]  2.6842105  3.0000000
```

1.4 A matrix for storing the density at point (x[I], y[j])

```
> z<-matrix(0,ncol=20,nrow=20)  # nrow = # of rows
> z
```

```
      [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8] [,9] [,10] [,11] [,12] [,13]
 [1,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [2,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [3,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [4,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [5,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [6,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [7,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [8,]    0    0    0    0    0    0    0    0    0     0     0     0     0
 [9,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[10,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[11,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[12,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[13,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[14,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[15,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[16,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[17,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[18,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[19,]    0    0    0    0    0    0    0    0    0     0     0     0     0
[20,]    0    0    0    0    0    0    0    0    0     0     0     0     0
      [,14] [,15] [,16] [,17] [,18] [,19] [,20]
 [1,]     0     0     0     0     0     0     0
 [2,]     0     0     0     0     0     0     0
 [3,]     0     0     0     0     0     0     0
 [4,]     0     0     0     0     0     0     0
 [5,]     0     0     0     0     0     0     0
 [6,]     0     0     0     0     0     0     0
 [7,]     0     0     0     0     0     0     0
 [8,]     0     0     0     0     0     0     0
 [9,]     0     0     0     0     0     0     0
[10,]     0     0     0     0     0     0     0
[11,]     0     0     0     0     0     0     0
[12,]     0     0     0     0     0     0     0
[13,]     0     0     0     0     0     0     0
[14,]     0     0     0     0     0     0     0
[15,]     0     0     0     0     0     0     0
[16,]     0     0     0     0     0     0     0
[17,]     0     0     0     0     0     0     0
[18,]     0     0     0     0     0     0     0
[19,]     0     0     0     0     0     0     0
[20,]     0     0     0     0     0     0     0
```

1.5 Compute the density over the matrix

```
> for(i in 1:20){
+  for(j in 1:20){
+  z[i,j]<-dbinorm(c(x[i],y[j]),mu,sigma)
+  }}
> z
```

```
              [,1]         [,2]         [,3]         [,4]         [,5]
 [1,] 1.964128e-05 4.818946e-05 0.0001070102 0.0002150747 0.0003912408
 [2,] 4.818946e-05 1.182318e-04 0.0002625473 0.0005276811 0.0009599010
 [3,] 1.070102e-04 2.625473e-04 0.0005830163 0.0011717764 0.0021315701
 [4,] 2.150747e-04 5.276811e-04 0.0011717764 0.0023550968 0.0042841397
 [5,] 3.912408e-04 9.599010e-04 0.0021315701 0.0042841397 0.0077932480
 [6,] 6.441542e-04 1.580419e-03 0.0035095007 0.0070535760 0.0128311098
 [7,] 9.599010e-04 2.355097e-03 0.0052297619 0.0105110458 0.0191205685
 [8,] 1.294654e-03 3.176407e-03 0.0070535760 0.0141766418 0.0257886279
 [9,] 1.580419e-03 3.877524e-03 0.0086104855 0.0173057990 0.0314808555
[10,] 1.746149e-03 4.284140e-03 0.0095134225 0.0191205685 0.0347820897
[11,] 1.746149e-03 4.284140e-03 0.0095134225 0.0191205685 0.0347820897
[12,] 1.580419e-03 3.877524e-03 0.0086104855 0.0173057990 0.0314808555
[13,] 1.294654e-03 3.176407e-03 0.0070535760 0.0141766418 0.0257886279
[14,] 9.599010e-04 2.355097e-03 0.0052297619 0.0105110458 0.0191205685
[15,] 6.441542e-04 1.580419e-03 0.0035095007 0.0070535760 0.0128311098
[16,] 3.912408e-04 9.599010e-04 0.0021315701 0.0042841397 0.0077932480
[17,] 2.150747e-04 5.276811e-04 0.0011717764 0.0023550968 0.0042841397
[18,] 1.070102e-04 2.625473e-04 0.0005830163 0.0011717764 0.0021315701
[19,] 4.818946e-05 1.182318e-04 0.0002625473 0.0005276811 0.0009599010
[20,] 1.964128e-05 4.818946e-05 0.0001070102 0.0002150747 0.0003912408
              [,6]        [,7]        [,8]        [,9]       [,10]       [,11]
 [1,] 0.0006441542 0.000959901 0.001294654 0.001580419 0.001746149 0.001746149
 [2,] 0.0015804188 0.002355097 0.003176407 0.003877524 0.004284140 0.004284140
 [3,] 0.0035095007 0.005229762 0.007053576 0.008610486 0.009513423 0.009513423
 [4,] 0.0070535760 0.010511046 0.014176642 0.017305799 0.019120568 0.019120568
 [5,] 0.0128311098 0.019120568 0.025788628 0.031480855 0.034782090 0.034782090
 [6,] 0.0211256434 0.031480855 0.042459411 0.051831318 0.057266599 0.057266599
 [7,] 0.0314808555 0.046911909 0.063271851 0.077237611 0.085337119 0.085337119
 [8,] 0.0424594105 0.063271851 0.085337119 0.104173262 0.115097373 0.115097373
 [9,] 0.0518313177 0.077237611 0.104173262 0.127167038 0.140502386 0.140502386
[10,] 0.0572665995 0.085337119 0.115097373 0.140502386 0.155236144 0.155236144
[11,] 0.0572665995 0.085337119 0.115097373 0.140502386 0.155236144 0.155236144
[12,] 0.0518313177 0.077237611 0.104173262 0.127167038 0.140502386 0.140502386
[13,] 0.0424594105 0.063271851 0.085337119 0.104173262 0.115097373 0.115097373
[14,] 0.0314808555 0.046911909 0.063271851 0.077237611 0.085337119 0.085337119
[15,] 0.0211256434 0.031480855 0.042459411 0.051831318 0.057266599 0.057266599
[16,] 0.0128311098 0.019120568 0.025788628 0.031480855 0.034782090 0.034782090
[17,] 0.0070535760 0.010511046 0.014176642 0.017305799 0.019120568 0.019120568
```

```
[18,] 0.0035095007 0.005229762 0.007053576 0.008610486 0.009513423 0.009513423
[19,] 0.0015804188 0.002355097 0.003176407 0.003877524 0.004284140 0.004284140
[20,] 0.0006441542 0.000959901 0.001294654 0.001580419 0.001746149 0.001746149
            [,12]       [,13]       [,14]        [,15]        [,16]
 [1,] 0.001580419 0.001294654 0.000959901 0.0006441542 0.0003912408
 [2,] 0.003877524 0.003176407 0.002355097 0.0015804188 0.0009599010
 [3,] 0.008610486 0.007053576 0.005229762 0.0035095007 0.0021315701
 [4,] 0.017305799 0.014176642 0.010511046 0.0070535760 0.0042841397
 [5,] 0.031480855 0.025788628 0.019120568 0.0128311098 0.0077932480
 [6,] 0.051831318 0.042459411 0.031480855 0.0211256434 0.0128311098
 [7,] 0.077237611 0.063271851 0.046911909 0.0314808555 0.0191205685
 [8,] 0.104173262 0.085337119 0.063271851 0.0424594105 0.0257886279
 [9,] 0.127167038 0.104173262 0.077237611 0.0518313177 0.0314808555
[10,] 0.140502386 0.115097373 0.085337119 0.0572665995 0.0347820897
[11,] 0.140502386 0.115097373 0.085337119 0.0572665995 0.0347820897
[12,] 0.127167038 0.104173262 0.077237611 0.0518313177 0.0314808555
[13,] 0.104173262 0.085337119 0.063271851 0.0424594105 0.0257886279
[14,] 0.077237611 0.063271851 0.046911909 0.0314808555 0.0191205685
[15,] 0.051831318 0.042459411 0.031480855 0.0211256434 0.0128311098
[16,] 0.031480855 0.025788628 0.019120568 0.0128311098 0.0077932480
[17,] 0.017305799 0.014176642 0.010511046 0.0070535760 0.0042841397
[18,] 0.008610486 0.007053576 0.005229762 0.0035095007 0.0021315701
[19,] 0.003877524 0.003176407 0.002355097 0.0015804188 0.0009599010
[20,] 0.001580419 0.001294654 0.000959901 0.0006441542 0.0003912408
            [,17]        [,18]        [,19]        [,20]
 [1,] 0.0002150747 0.0001070102 4.818946e-05 1.964128e-05
 [2,] 0.0005276811 0.0002625473 1.182318e-04 4.818946e-05
 [3,] 0.0011717764 0.0005830163 2.625473e-04 1.070102e-04
 [4,] 0.0023550968 0.0011717764 5.276811e-04 2.150747e-04
 [5,] 0.0042841397 0.0021315701 9.599010e-04 3.912408e-04
 [6,] 0.0070535760 0.0035095007 1.580419e-03 6.441542e-04
 [7,] 0.0105110458 0.0052297619 2.355097e-03 9.599010e-04
 [8,] 0.0141766418 0.0070535760 3.176407e-03 1.294654e-03
 [9,] 0.0173057990 0.0086104855 3.877524e-03 1.580419e-03
[10,] 0.0191205685 0.0095134225 4.284140e-03 1.746149e-03
[11,] 0.0191205685 0.0095134225 4.284140e-03 1.746149e-03
[12,] 0.0173057990 0.0086104855 3.877524e-03 1.580419e-03
[13,] 0.0141766418 0.0070535760 3.176407e-03 1.294654e-03
[14,] 0.0105110458 0.0052297619 2.355097e-03 9.599010e-04
[15,] 0.0070535760 0.0035095007 1.580419e-03 6.441542e-04
[16,] 0.0042841397 0.0021315701 9.599010e-04 3.912408e-04
[17,] 0.0023550968 0.0011717764 5.276811e-04 2.150747e-04
[18,] 0.0011717764 0.0005830163 2.625473e-04 1.070102e-04
[19,] 0.0005276811 0.0002625473 1.182318e-04 4.818946e-05
[20,] 0.0002150747 0.0001070102 4.818946e-05 1.964128e-05
```

1.6 Plot the result in two ways

```
> persp(x,y,z)  #  Creates a perspective plot
> contour(x,y,z)  #  Make a contour plot
```

1.7 letąęs construct a distribution with some correlation

```
> sigmac<-matrix(c(sqrt(2),1,1,sqrt(2)),ncol=2)
> sigmac

         [,1]     [,2]
[1,] 1.414214 1.000000
[2,] 1.000000 1.414214

> for(i in 1:20){
+  for(j in 1:20){
+  z[i,j]<-dbinorm(c(x[i],y[j]),mu,sigmac)
+  }}
> persp(x,y,z)
> contour(x,y,z)
```