

# Lab 4 732A97

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**Question: Canonical correlation analysis by utilizing suitable software**

**Data**

```
library(dplyr); library(knitr)
```

```
S <- as.matrix(read.table("P10-16.dat")); S
```

```
##           V1           V2           V3           V4           V5
## [1,] 1106.000  396.700  108.400  0.787  26.230
## [2,]  396.700 2382.000 1143.000 -0.214 -23.960
## [3,]  108.400 1143.000 2136.000  2.189 -20.840
## [4,]    0.787   -0.214    2.189  0.016   0.216
## [5,]   26.230  -23.960  -20.840  0.216  70.560
```

```
R <- cov2cor(S); kable(R)
```

V1	V2	V3	V4	V5
1.0000000	0.2444071	0.0705263	0.1870842	0.0938948
0.2444071	1.0000000	0.5067278	-0.0346643	-0.0584436
0.0705263	0.5067278	1.0000000	0.3744425	-0.0536807
0.1870842	-0.0346643	0.3744425	1.0000000	0.2032893
0.0938948	-0.0584436	-0.0536807	0.2032893	1.0000000

```
## ![Assignment4](10p16.PNG)
```

10.16. Andrews and Herzberg [1] give data obtained from a study of a comparison of nondiabetic and diabetic patients. Three primary variables,

$X_1^{(1)}$  = glucose intolerance

$X_2^{(1)}$  = insulin response to oral glucose

$X_3^{(1)}$  = insulin resistance

and two secondary variables,

$X_1^{(2)}$  = relative weight.

$X_2^{(2)}$  = fasting plasma glucose

were measured. The data for  $n = 46$  nondiabetic patients yield the covariance matrix

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \begin{bmatrix} 1106.000 & 396.700 & 108.400 & .787 & 26.230 \\ 396.700 & 2382.000 & 1143.000 & -.214 & -23.960 \\ 108.400 & 1143.000 & 2136.000 & 2.189 & -20.840 \\ .787 & -.214 & 2.189 & .016 & .216 \\ 26.230 & -23.960 & -20.840 & .216 & 70.560 \end{bmatrix}$$

Determine the sample canonical variates and their correlations. Interpret these quantities. Are the first canonical variates good summary measures of their respective sets of variables? Explain. Test for the significance of the canonical relations with  $\alpha = .05$ .

a) Test at the 5% level if there is any association between the groups of variables.

```
inverse_sqrtm <- function(M){
  stopifnot(is.matrix(M))

  U <- eigen(M)$vectors
  D <- diag(eigen(M)$values)
  # print ( U%%D%%solve(U) ) # should be same as M
  M_sqrt_inv <- U%%solve(sqrt(D))%%solve(U)
  return(M_sqrt_inv)
}

ccm_Func <- function(M, p, q, z=FALSE){

  M11=M[1:p, 1:p]; M12=M[1:p, (p+1):(p+q)]
  M21=t(M[1:p, (p+1):(p+q)]); M22=M[(p+1):(p+q), (p+1):(p+q)]
  CCM1=inverse_sqrtm(M11)%%M12%%solve(M22)%%M21%%inverse_sqrtm(M11)
  squared_rhos <- eigen(CCM1)$values
  # rhos <- sqrt(squared_rhos)
  e_vectors <- eigen(CCM1)$vectors

  return(squared_rhos)
}

R_res = ccm_Func(S,p=3,q=2); R_res
```

```
## [1] 2.676458e-01 1.575231e-02 1.861793e-17
```

```
test_statistic <- function(n,p,q, squared_rhos){
  -(n-1-0.5*(p+q+1))*log(prod(1-squared_rhos)) }
n = 46; p=3; q=2
t <- test_statistic(n=n, p=p, q=q, squared_rhos=R_res)
c <- qchisq(p=1-0.05, df=p*q)

kable(t(c(t,c, as.character(t>c) )),
      col.names=c("Test Statistic", "Critical Value", "Check t > c"), digits = 3)
```

Test Statistic	Critical Value	Check t > c
13.7494849041102	12.591587243744	TRUE

We REJECT the null hypothesis at 5% significance level. Therefore we can say that that is SIGNIFICANT correlation between the groups of variables. The test statistic 13.7494849 is GREATER than the critical value 12.5915872.

b) How many pairs of canonical variates are significant?

```
options(digits=7); sqrt(R_res)
```

```
## [1] 5.173449e-01 1.255082e-01 4.314850e-09
```

There are two significant canonical correlations 0.5173449, 0.1255082 because they are not very close to zero.

c) Interpret the “significant” squared canonical correlations.

**Tip:** Read section “Canonical Correlations as Generalizations of Other Correlation Coefficients”.

“Glucose intolerance” and “insulin response to oral glucose” have a recognizable effect on “relative weight” and “fasting plasma resistance” among patients. Patients who are glucose intolerant will tend to be fatter.

d) Interpret the canonical variates by using the coefficients and suitable correlations.

```
A_B_calc_Func <- function(M, p, q, z=FALSE, significant=2){  
  
  M11=M[1:p, 1:p]; M12=M[1:p, (p+1):(p+q)]  
  M21=t(M[1:p, (p+1):(p+q)]); M22=M[(p+1):(p+q), (p+1):(p+q)]  
  CCM1=inverse_sqrtm(M11)%*%M12%*%solve(M22)%*%M21%*%inverse_sqrtm(M11)  
  squared_rhos <- eigen(CCM1)$values  
  # rhos <- sqrt(squared_rhos)  
  e_vectors <- eigen(CCM1)$vectors[,1:significant]  
  
  if(z==TRUE){  
    a_s <- inverse_sqrtm(M11)%*%e_vectors  
    f_vectors <- inverse_sqrtm(M22)%*%M21%*%inverse_sqrtm(M11)%*%e_vectors  
    b_s <- inverse_sqrtm(M22)%*%f_vectors  
  }else{  
    a_s <- t(e_vectors)%*%inverse_sqrtm(M11); print(a_s)  
    ff <- (1/(sqrt(squared_rhos)))[1:significant]  
    f_vectors <- ff*inverse_sqrtm(M22)%*%M21%*%inverse_sqrtm(M11)%*%e_vectors  
    b_s <- t(f_vectors)%*%inverse_sqrtm(M22); print(b_s)  
  }  
  
  return(list(a_s=a_s, b_s=b_s))  
}
```

```
U_V = A_B_calc_Func(S,p=3,q=2, significant = 2)
```

```
##           [,1]           [,2]           [,3]  
## [1,] 0.01310065 -0.014438254 0.023399723  
## [2,] 0.02475248 -0.009317525 -0.008667216  
##           [,1]           [,2]  
## [1,] 8.0622708 -0.0029998  
## [2,] -0.1094472 0.1192659
```

```
options(digits=10)
kable(U_V$a_s, col.names=sapply(1:ncol(U_V$a_s),
                                FUN=function(i) paste0("a_",i)) )
```

a_1	a_2	a_3
0.0131006541	-0.0144382541	0.0233997230
0.0247524811	-0.0093175253	-0.0086672162

```
kable(U_V$b_s, col.names=sapply(1:ncol(U_V$b_s),
                                FUN=function(i) paste0("b_",i)) )
```

b_1	b_2
8.0622708375	-0.0029998004
-0.1094472452	0.1192659025

```
options(digits=3)
```

Because in this case the correlation matrix was used,  $U$  and  $V$  are the canonical variates and they are expressed as  $U = aX$  and  $V = bX$  where  $X$  is the variables and  $a$  and  $b$  are the vectors of the coefficients of the linear combinations of the variates that summarise the correlation between the variables.

A 0.013 **change** in “Glucose intolerance” and a 0.025 **change** in “insulin response to oral glucose” are significantly correlated with a 8.062 **change** in “relative weight” and a -0.109 **change** in “fasting plasma resistance”.

e) Are the “significant” canonical variates good summary measures of the respective data sets?

Tip: Read section “Proportions of Explained Sample Variance”.

f) Give your opinion on the success of this canonical correlation analysis.