Principle component analysis

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CSCI 548 – Douglas W. Raiford – Pattern Recognition

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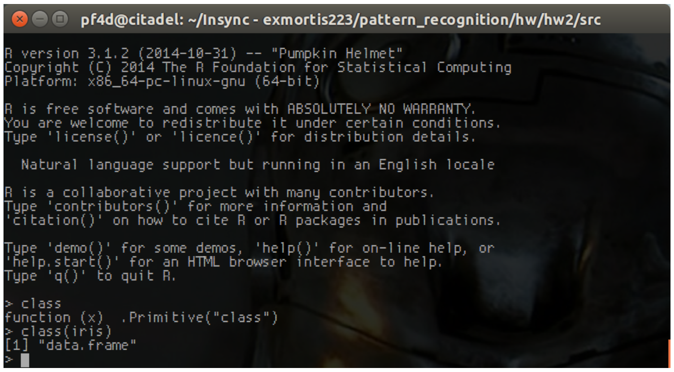
1 class command :

The class of the iris dataset is a data.frame, a “tightly coupled collections of variables which share many of the properties of matrices and of lists, used as the fundamental data structure by most of R’s modeling software.”


pf4d@citadel: ~/Insync - exmortis223/pattern_recognition/hw/hw2/src

```
R version 3.1.2 (2014-10-31) -- "Pumpkin Helmet"
Copyright (C) 2014 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)

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Type 'license()' or 'licence()' for distribution details.

  Natural language support but running in an English locale

R is a collaborative project with many contributors.
Type 'contributors()' for more information and
'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

> class
function (x)  .Primitive("class")
> class(iris)
[1] "data.frame"
> 
```
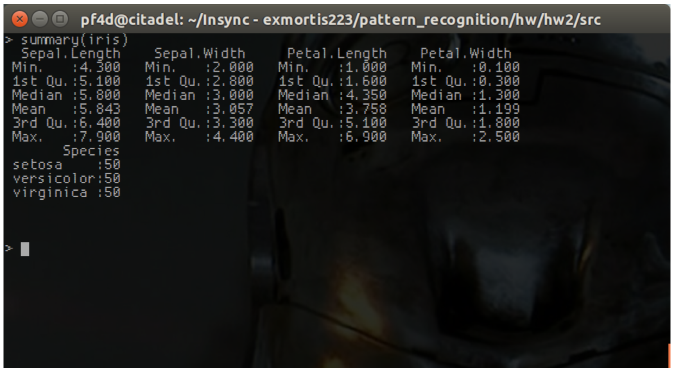

2 summary command :

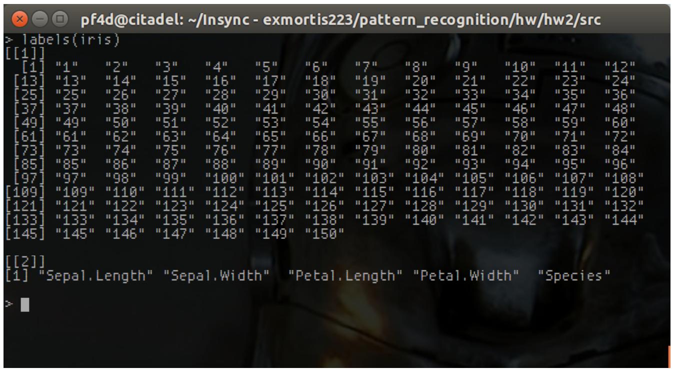
The summary command applied to the iris dataset, is a “generic function used to produce result summaries of the results of various model fitting functions. The function invokes particular methods which depend on the ‘class’ of the first argument.”


pf4d@citadel: ~/Insync - exmortis223/pattern_recognition/hw/hw2/src

```
> summary(iris)
  Sepal.Length    Sepal.Width     Petal.Length    Petal.Width   
 Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.   :0.100  
 1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300  
 Median :5.800   Median :3.000   Median :4.350   Median :1.300  
 Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199  
 3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800  
 Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.   :2.500  
       Species  
 setosa    :50  
 versicolor:50  
 virginica :50  



> 
```

3 labels command :

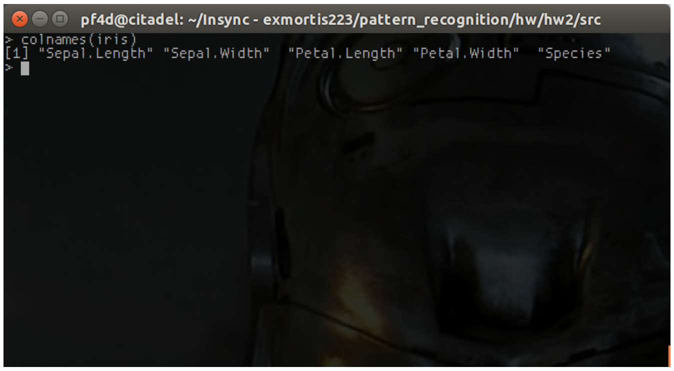
The labels command: “Find[s] a suitable set of labels from an object for use in printing or plotting. For example, a generic function.”


pf4d@citadel: ~/Insync - exmortis223/pattern_recognition/hw/hw2/src

```
> labels(iris)
[[1]]
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12" 
 [13] "13"  "14"  "15"  "16"  "17"  "18"  "19"  "20"  "21"  "22"  "23"  "24" 
 [25] "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "33"  "34"  "35"  "36" 
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48" 
 [49] "49"  "50"  "51"  "52"  "53"  "54"  "55"  "56"  "57"  "58"  "59"  "60" 
 [61] "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72" 
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84" 
 [85] "85"  "86"  "87"  "88"  "89"  "90"  "91"  "92"  "93"  "94"  "95"  "96" 
 [97] "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "108"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "120"
[121] "121" "122" "123" "124" "125" "126" "127" "128" "129" "130" "131" "132"
[133] "133" "134" "135" "136" "137" "138" "139" "140" "141" "142" "143" "144"
[145] "145" "146" "147" "148" "149" "150"

[[2]]
[1] "Sepal.Length" "Sepal.Width"  "Petal.Length" "Petal.Width"  "Species"     

> 
```

4 colnames command :

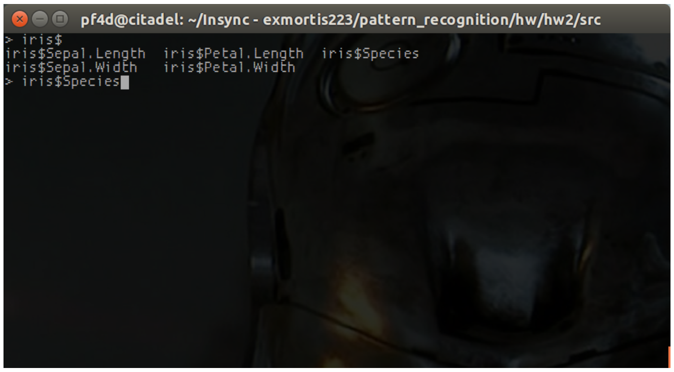
The colnames command: “Retrieve[s] or set[s] the row or column names of a matrix-like object.”


pf4d@citadel: ~/Insync - exmortis223/pattern_recognition/hw/hw2/src

```
> colnames(iris)
[1] "Sepal.Length" "Sepal.Width"  "Petal.Length" "Petal.Width"  "Species"     
> 
```

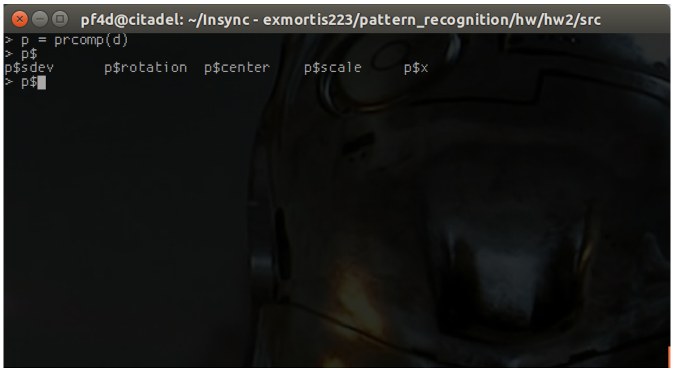
5 tab-completion :

Pressing tab after a data.frame object with accessor-operator $ will provide variable names.


pf4d@citadel: ~/Insync - exmortis223/pattern_recognition/hw/hw2/src

```
> iris$
iris$Sepal.Length  iris$Petal.Length  iris$Species
iris$Sepal.Width   iris$Petal.Width
> iris$Species
```

6 Iris data PCA plotting :


pf4d@citadel: ~/Insync - exmortis223/pattern_recognition/hw/hw2/src

```
> p = prcomp(d)
> p$
p$sdev       p$rotation  p$center    p$scale     p$x
> p$
```

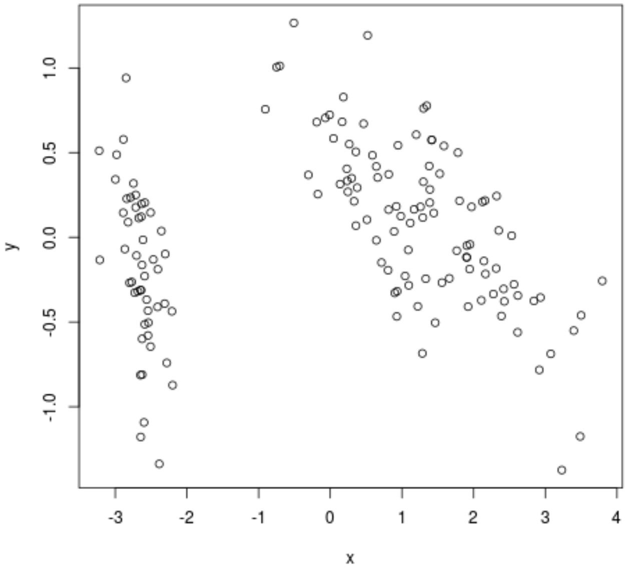
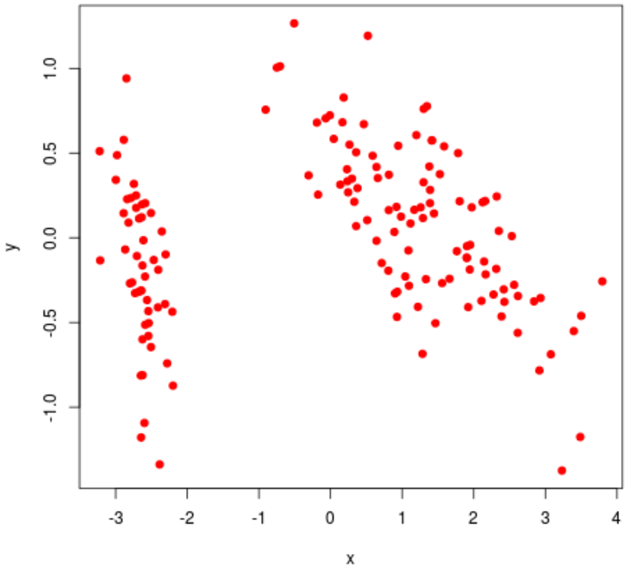
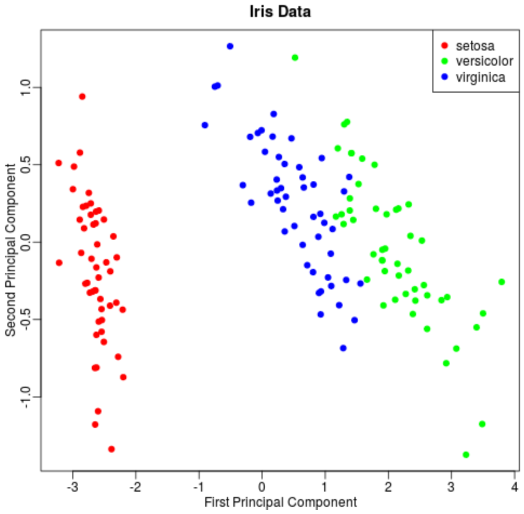


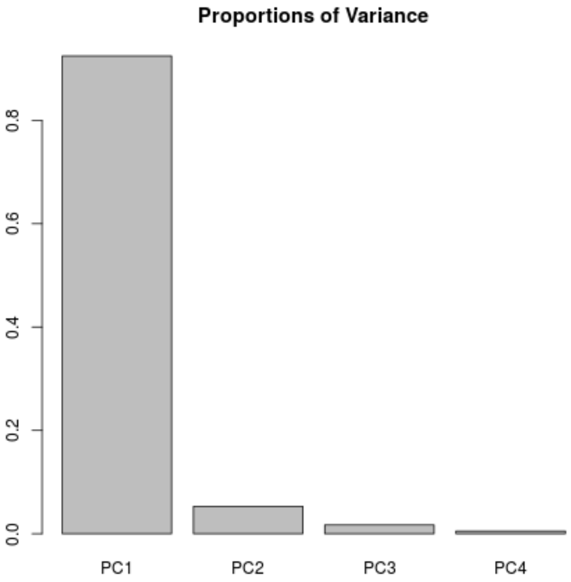
Figure 1: PCA-plot showing what appears to be two clusters, despite the fact that there are three distinct species of iris.

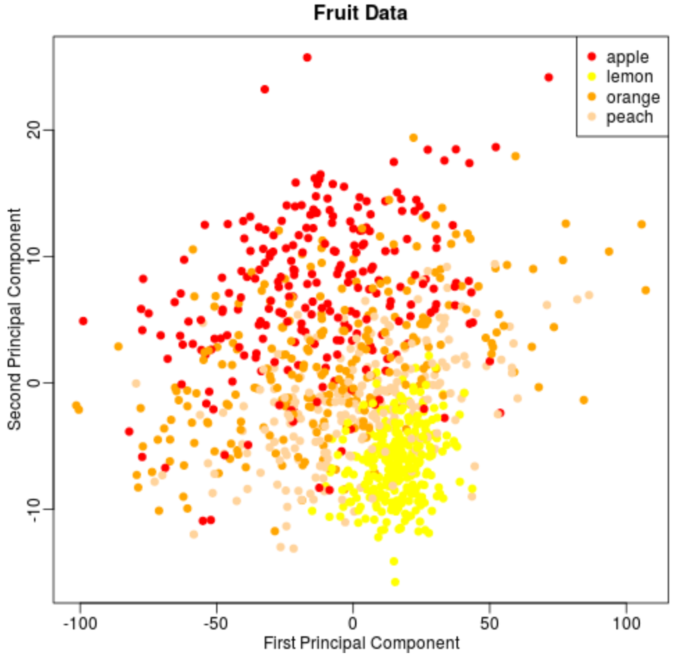
The plot command, a “Generic function for plotting of R objects. For more details about the graphical parameter arguments, see ‘par’.

For simple scatter plots, plot.default will be used. However, there are plot methods for many R objects, including function’s, data.frame’s, density objects, etc. Use methods(plot) and the documentation for these.”









6.1 Source code :

```
# store the iris ’classes’ :
c = iris[,5]

# store the iris ’data’ :
d = iris[,seq(1,4)]

# perform PCA on d :
p = prcomp(d)

# set the 1st principle component :
x = p$x[,1]

# set the 2nd principle component :
y = p$x[,2]

# plot them :
png(’../doc/images/pca_plot.png’)
plot(x,y)
dev.off()

# plot them in red :
png(’../doc/images/pca_plot_red.png’)
plot(x,y, col=’red’, bg=’red’, type=’p’, pch=21)
dev.off()

# store indexes of classes :
s  = which(c == ’setosa’)
vc = which(c == ’versicolor’)
vg = which(c == ’virginica’)

# color vector :
cc     = as.vector(c)
cc[s]  = ’red’
cc[vc] = ’blue’
cc[vg] = ’green’

# plot them colored by class :
png(’../doc/images/pca_plot_class.png’)
X11(width=4, height=4)
par(mar=c(2.5,2.5,2.5,.1),mgp = c(1.5, .5, 0))
plot(x,y, col=cc, bg=cc, type=’p’, pch=21, xlab=’First Principal Component’,
     ylab=’Second Principal Component’, main=’Iris Data’)
legend(’topright’, levels(c),
        col   = c(’red’, ’green’, ’blue’),
        pt.bg = c(’red’, ’green’, ’blue’), pch = 21)
dev.off()

# do a barplot of the proportions of variance :
sig  = p$sdev**2
pvar =  sig / sum(sig)
png(’../doc/images/pca_pvar_barplot.png’)
barplot(pvar, names.arg=c(’PC1’,’PC2’,’PC3’,’PC4’),
         main=’Proportions of Variance’)
dev.off()
```

7 Fruit data :

While the iris data appears to be highly grouped, the fruit data appears much less so. However, the lemons seem to be clustered distintly from the other fruit. Therefore, I believe that these data *do* show enough structure for machine learning techniques; with apples, oranges, and peaches potentially presenting the highest challenge.

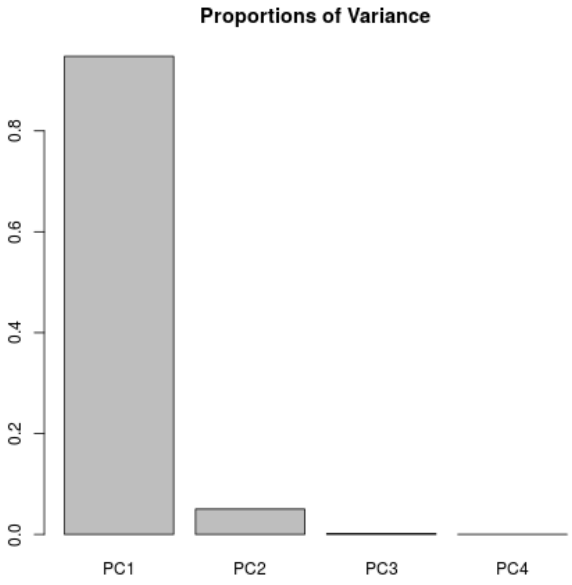


Figure 2: The proportions of the variance in the fruit data. The principle component captures ≈ 94% of the variation.

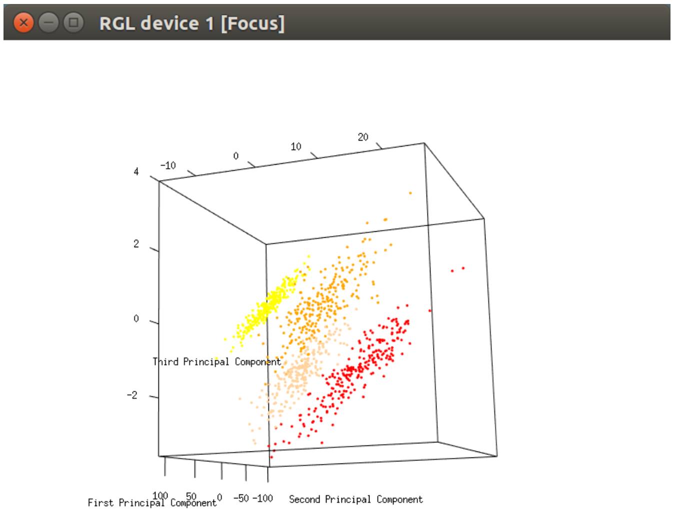

RGL device 1 [Focus]
-10
0
10
20
4
2
0
-2
Third Principal Component
100
50
0
-50
-100
First Principal Component
Second Principal Component

Figure 3: In 3D, we can see much more distinct clustering.

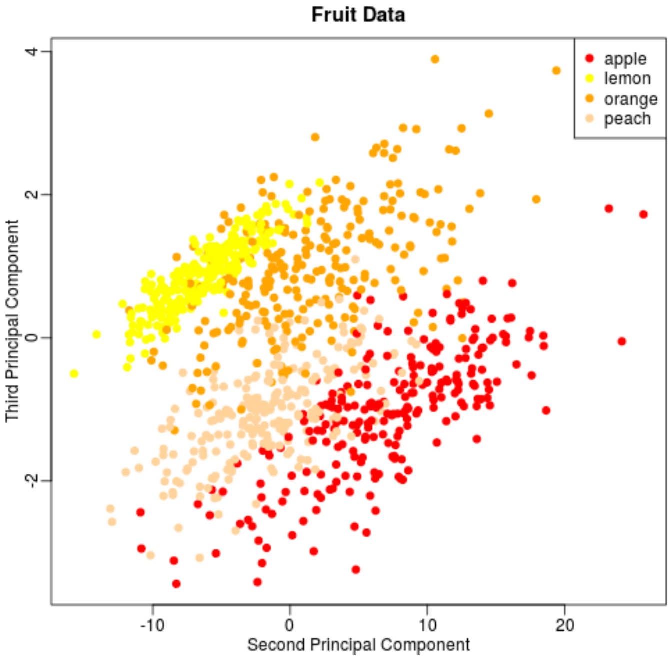


Figure 4: The second and third principle components, highlighting the clustering nature of the fruit data.

7.1 Source code :

```
# read the variable back in :
f = read.csv("../data/fruit.csv")

# store the fruit 'classes' :
c = f[,5]

# store the fruit 'data' :
d = f[,seq(1,4)]

# perform PCA on d :
p = prcomp(d)

# set the 1st principle component :
x = p$x[,1]

# set the 2nd principle component :
y = p$x[,2]

# set the 3nd principle component :
z = p$x[,3]

# store indexes of classes :
a = which(c == 'apple')
l = which(c == 'lemon')
o = which(c == 'orange')
z = which(c == 'peach')

# color vector :
cols  = c('red', 'yellow', 'orange', 'burlywood1')
cc    = as.vector(c)
cc[a] = cols[1]
cc[l] = cols[2]
cc[o] = cols[3]
cc[z] = cols[4]

# plot them colored by class :
png('../doc/images/pca_plot_fruit.png')
#X11(width=4, height=4)
par(mar=c(2.5,2.5,2.5,.1),mgp = c(1.5, .5, 0))
plot(x,y, col=cc, bg=cc, type='p', pch=21, xlab='First Principal Component',
     ylab='Second Principal Component', main='Fruit Data')
legend('topright', levels(c), col = cols, pt.bg = cols, pch = 21)
dev.off()

# do a barplot of the proportions of variance :
sig  = p$sdev**2
pvar =  sig / sum(sig)
png('../doc/images/pca_pvar_fruit_barplot.png')
barplot(pvar, names.arg=c('PC1','PC2','PC3','PC4'),
        main='Proportions of Variance')
dev.off()

# import the rgl library for 3D stuff:
library(rgl)

plot3d(x,y,z, col=cc, bg=cc, type='p', pch=21,
       xlab='First Principal Component',
       ylab='Second Principal Component',
       zlab='Third Principal Component')

# plot them colored by class :
png('../doc/images/pca_plot_fruit_23.png')
#X11(width=4, height=4)
par(mar=c(2.5,2.5,2.5,.1),mgp = c(1.5, .5, 0))
plot(y,z, col=cc, bg=cc, type='p', pch=21, xlab='Second Principal Component',
     ylab='Third Principal Component', main='Fruit Data')
legend('topright', levels(c), col = cols, pt.bg = cols, pch = 21)
dev.off()
```