Clustering Flower Species and Principle Component Analysis

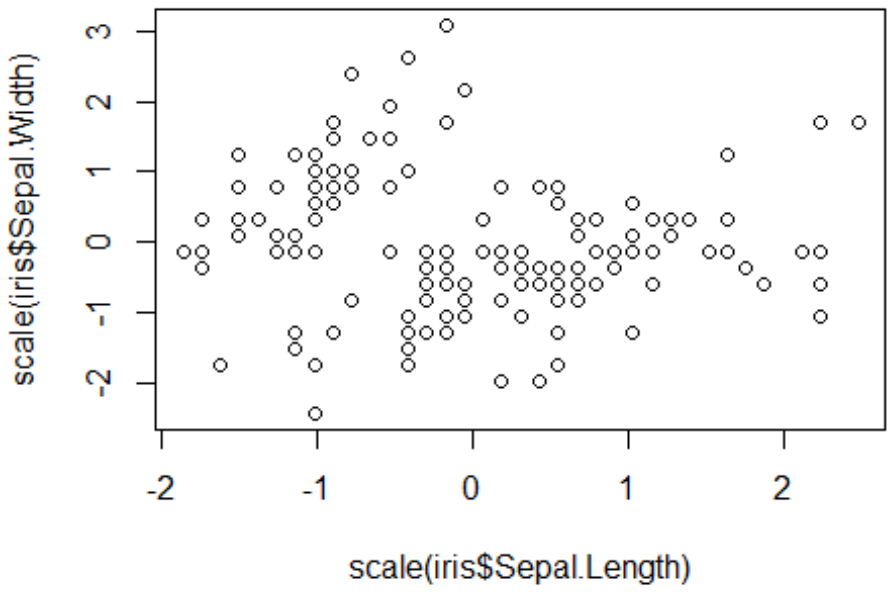
Load and Explore Data

```
data(iris)
head(iris,30)
```

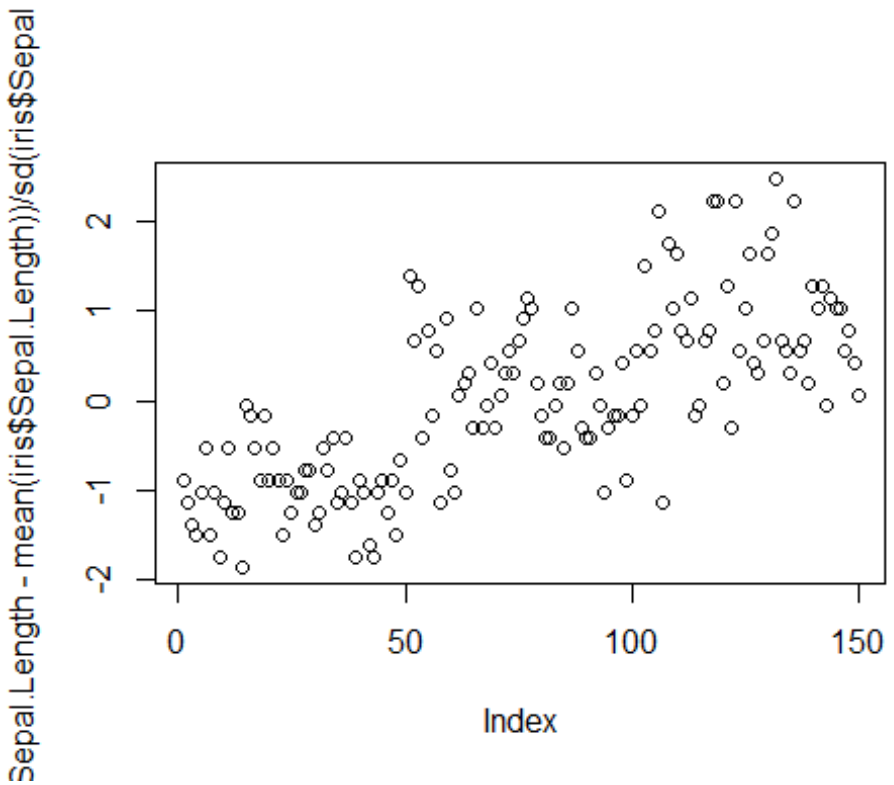
```
##    Sepal.Length Sepal.Width Petal.Length Petal.Width Species
## 1           5.1         3.5          1.4         0.2  setosa
## 2           4.9         3.0          1.4         0.2  setosa
## 3           4.7         3.2          1.3         0.2  setosa
## 4           4.6         3.1          1.5         0.2  setosa
## 5           5.0         3.6          1.4         0.2  setosa
## 6           5.4         3.9          1.7         0.4  setosa
## 7           4.6         3.4          1.4         0.3  setosa
## 8           5.0         3.4          1.5         0.2  setosa
## 9           4.4         2.9          1.4         0.2  setosa
## 10          4.9         3.1          1.5         0.1  setosa
## 11          5.4         3.7          1.5         0.2  setosa
## 12          4.8         3.4          1.6         0.2  setosa
## 13          4.8         3.0          1.4         0.1  setosa
## 14          4.3         3.0          1.1         0.1  setosa
## 15          5.8         4.0          1.2         0.2  setosa
## 16          5.7         4.4          1.5         0.4  setosa
## 17          5.4         3.9          1.3         0.4  setosa
## 18          5.1         3.5          1.4         0.3  setosa
## 19          5.7         3.8          1.7         0.3  setosa
## 20          5.1         3.8          1.5         0.3  setosa
## 21          5.4         3.4          1.7         0.2  setosa
## 22          5.1         3.7          1.5         0.4  setosa
## 23          4.6         3.6          1.0         0.2  setosa
## 24          5.1         3.3          1.7         0.5  setosa
## 25          4.8         3.4          1.9         0.2  setosa
## 26          5.0         3.0          1.6         0.2  setosa
## 27          5.0         3.4          1.6         0.4  setosa
## 28          5.2         3.5          1.5         0.2  setosa
## 29          5.2         3.4          1.4         0.2  setosa
## 30          4.7         3.2          1.6         0.2  setosa
```

Relation between Sepal Length and Sepal Width

```
plot(scale(iris$Sepal.Length), scale(iris$Sepal.Width))
```




```
plot((iris$Sepal.Length - mean(iris$Sepal.Length)) / sd(iris$Sepal.Length))
```



Applying Pricipal Component Analysis (PCA) on Independent Variables

```
iris_x <-iris[,1:4]

iris.pca.rawdata <- prcomp(iris_x, scale = FALSE, center= FALSE)
iris.pca.rawdata
```

```
## Standard deviations (1, .., p=4):
## [1] 7.8613425 1.4550406 0.2835305 0.1544110
##
## Rotation (n x k) = (4 x 4):
##                      PC1        PC2         PC3        PC4
## Sepal.Length -0.7511082  0.2841749  0.50215472  0.3208143
## Sepal.Width  -0.3800862  0.5467445 -0.67524332 -0.3172561
## Petal.Length -0.5130089 -0.7086646 -0.05916621 -0.4807451
## Petal.Width  -0.1679075 -0.3436708 -0.53701625  0.7518717
```

```
summary(iris.pca.rawdata)
```

```
## Importance of components:
##                            PC1     PC2     PC3     PC4
## Standard deviation     7.8613 1.45504 0.28353 0.15441
## Proportion of Variance 0.9653 0.03307 0.00126 0.00037
## Cumulative Proportion  0.9653 0.99837 0.99963 1.00000
```

```
str(iris.pca.rawdata)
```

```
## List of 5
##  $ sdev    : num [1:4] 7.861 1.455 0.284 0.154
##  $ rotation: num [1:4, 1:4] -0.751 -0.38 -0.513 -0.168 0.284 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:4] "Sepal.Length" "Sepal.Width" "Petal.Length"
"Petal.Width"
##   .. ..$ : chr [1:4] "PC1" "PC2" "PC3" "PC4"
##  $ center  : logi FALSE
##  $ scale   : logi FALSE
##  $ x       : num [1:150, 1:4] -5.91 -5.57 -5.45 -5.44 -5.88 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : NULL
##   .. ..$ : chr [1:4] "PC1" "PC2" "PC3" "PC4"
##  - attr(*, "class")= chr "prcomp"
```

Normalize the Data

```
iris.pca.normaldata <- prcomp(iris_x, scale = TRUE, center= TRUE)
iris.pca.normaldata
```

```
## Standard deviations (1, .., p=4):
## [1] 1.7083611 0.9560494 0.3830886 0.1439265
##
## Rotation (n x k) = (4 x 4):
##                     PC1         PC2        PC3        PC4
## Sepal.Length  0.5210659 -0.37741762  0.7195664  0.2612863
## Sepal.Width  -0.2693474 -0.92329566 -0.2443818 -0.1235096
## Petal.Length  0.5804131 -0.02449161 -0.1421264 -0.8014492
## Petal.Width   0.5648565 -0.06694199 -0.6342727  0.5235971
```

```
summary(iris.pca.normaldata)
```

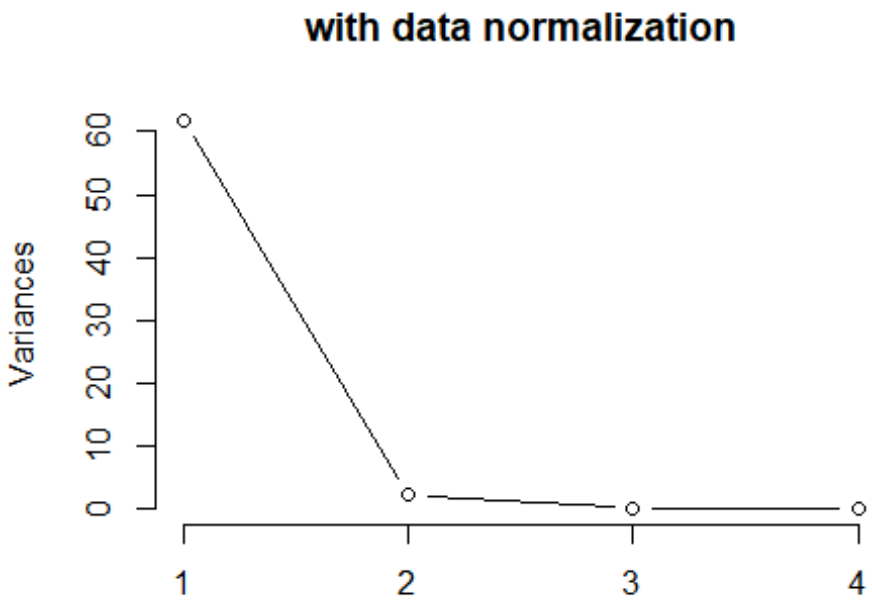
```
## Importance of components:
##                           PC1    PC2     PC3     PC4
## Standard deviation     1.7084 0.9560 0.38309 0.14393
## Proportion of Variance 0.7296 0.2285 0.03669 0.00518
## Cumulative Proportion  0.7296 0.9581 0.99482 1.00000
```

```
str(iris.pca.normaldata)
```

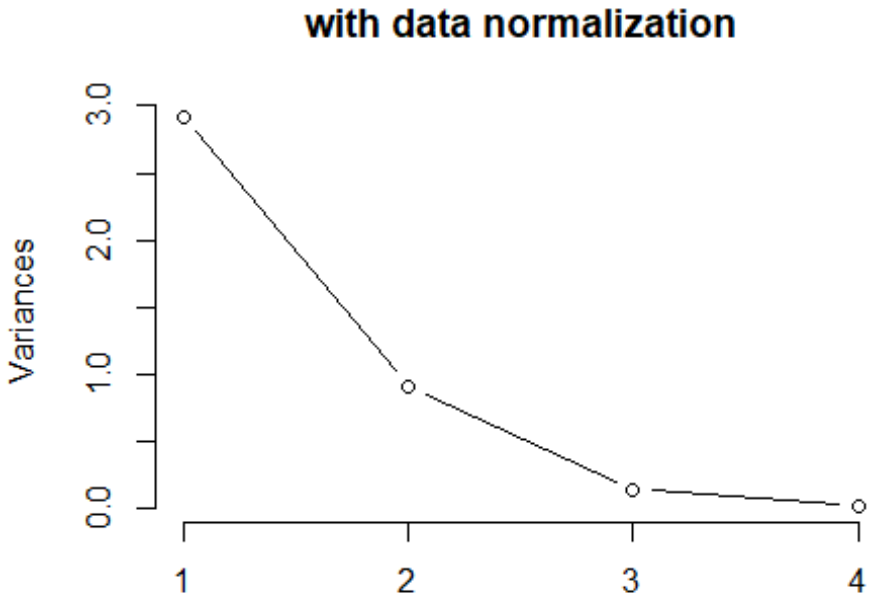
```
## List of 5
##  $ sdev    : num [1:4] 1.708 0.956 0.383 0.144
##  $ rotation: num [1:4, 1:4] 0.521 -0.269 0.58 0.565 -0.377 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : chr [1:4] "Sepal.Length" "Sepal.Width" "Petal.Length"
"Petal.Width"
##   .. ..$ : chr [1:4] "PC1" "PC2" "PC3" "PC4"
##  $ center  : Named num [1:4] 5.84 3.06 3.76 1.2
##   ..- attr(*, "names")= chr [1:4] "Sepal.Length" "Sepal.Width"
"Petal.Length" "Petal.Width"
##  $ scale   : Named num [1:4] 0.828 0.436 1.765 0.762
##   ..- attr(*, "names")= chr [1:4] "Sepal.Length" "Sepal.Width"
"Petal.Length" "Petal.Width"
##  $ x       : num [1:150, 1:4] -2.26 -2.07 -2.36 -2.29 -2.38 ...
##   ..- attr(*, "dimnames")=List of 2
##   .. ..$ : NULL
##   .. ..$ : chr [1:4] "PC1" "PC2" "PC3" "PC4"
##  - attr(*, "class")= chr "prcomp"
```

Variances of Components (Both Raw vs Normalized)

```
plot(iris.pca.rawdata, type = "l", main='with data normalization')
```

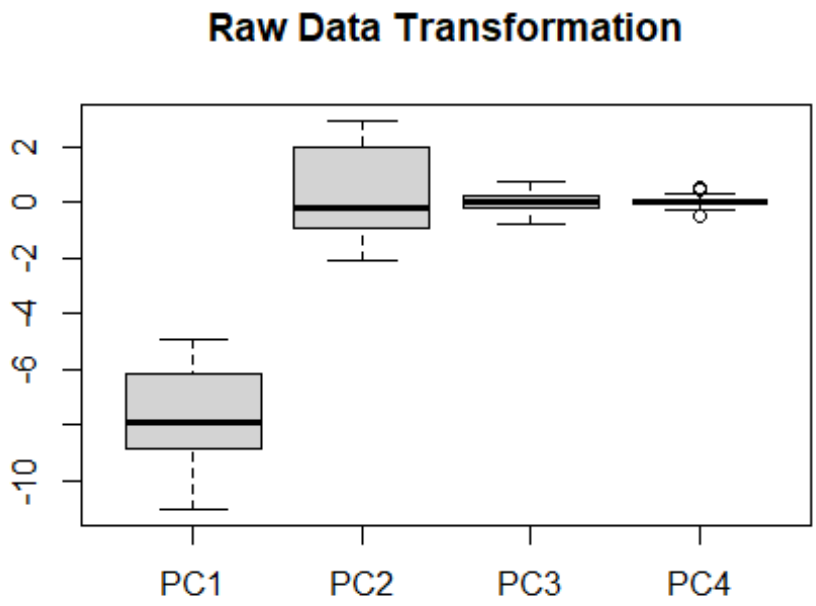



```
plot(iris.pca.normaldata, type = "l", main='with data normalization')
```

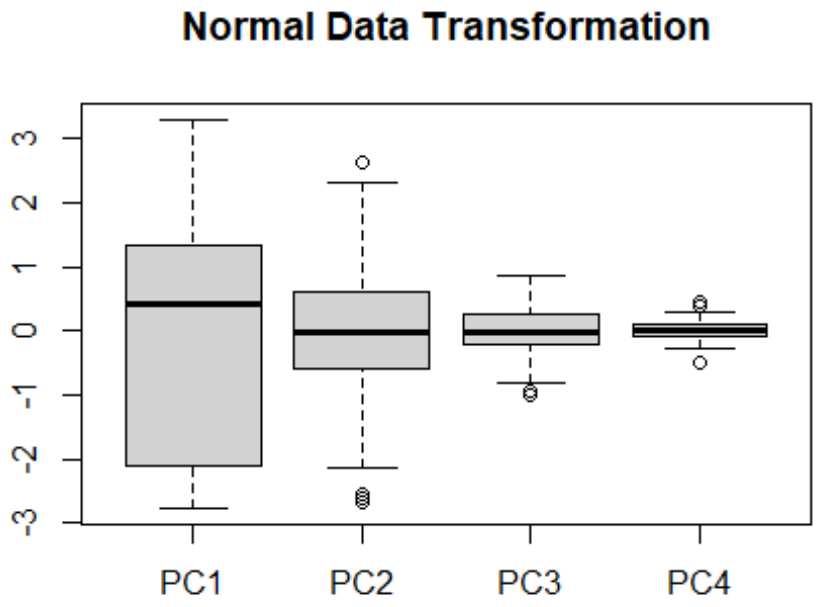


Comparing Boxplots of Raw vs Normal Datasets

```
boxplot(iris.pca.rawdata$x, main='Raw Data Transformation')
```

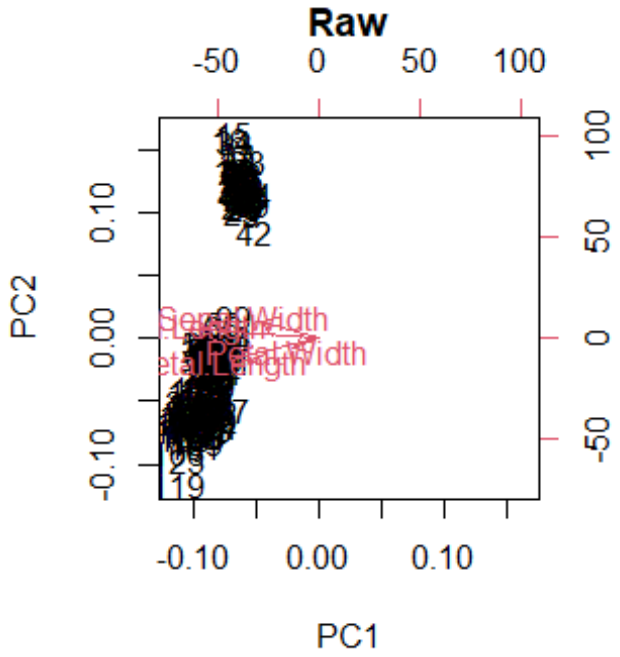



```
boxplot(iris.pca.normaldata$x, main='Normal Data Transformation')
```

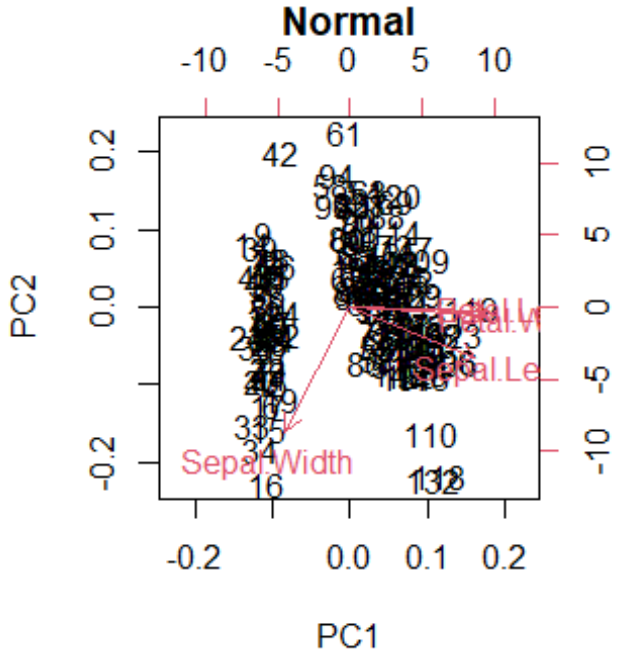


2-D Graph of PCA Components

```
biplot(iris.pca.rawdata, choices = 1:2, main='Raw')
```




```
biplot(iris.pca.normaldata, choices = 1:2, main='Normal')
```



Clustering the Species in Groups

```
iris.pca.normaldata$x
```

```
##                PC1          PC2          PC3          PC4
##   [1,] -2.25714118 -0.478423832  0.127279624  0.024087508
##   [2,] -2.07401302  0.671882687  0.233825517  0.102662845
##   [3,] -2.35633511  0.340766425 -0.044053900  0.028282305
##   [4,] -2.29170679  0.595399863 -0.090985297 -0.065735340
##   [5,] -2.38186270 -0.644675659 -0.015685647 -0.035802870
##   [6,] -2.06870061 -1.484205297 -0.026878250  0.006586116
##   [7,] -2.43586845 -0.047485118 -0.334350297 -0.036652767
##   [8,] -2.22539189 -0.222403002  0.088399352 -0.024529919
##   [9,] -2.32684533  1.111603700 -0.144592465 -0.026769540
##  [10,] -2.17703491  0.467447569  0.252918268 -0.039766068
##  [11,] -2.15907699 -1.040205867  0.267784001  0.016675503
##  [12,] -2.31836413 -0.132633999 -0.093446191 -0.133037725
##  [13,] -2.21104370  0.726243183  0.230140246  0.002416941
##  [14,] -2.62430902  0.958296347 -0.180192423 -0.019151375
##  [15,] -2.19139921 -1.853846555  0.471322025  0.194081578
##  [16,] -2.25466121 -2.677315230 -0.030424684  0.050365010
##  [17,] -2.20021676 -1.478655729  0.005326251  0.188186988
##  [18,] -2.18303613 -0.487206131  0.044067686  0.092779618
##  [19,] -1.89223284 -1.400327567  0.373093377  0.060891973
##  [20,] -2.33554476 -1.124083597 -0.132187626 -0.037630354
##  [21,] -1.90793125 -0.407490576  0.419885937  0.010884821
##  [22,] -2.19964383 -0.921035871 -0.159331502  0.059398340
##  [23,] -2.76508142 -0.456813301 -0.331069982  0.019582826
##  [24,] -1.81259716 -0.085272854 -0.034373442  0.150636353
##  [25,] -2.21972701 -0.136796175 -0.117599566 -0.269238379
##  [26,] -1.94532930  0.623529705  0.304620475  0.043416203
##  [27,] -2.04430277 -0.241354991 -0.086075649  0.067454082
##  [28,] -2.16133650 -0.525389422  0.206125707  0.010241084
##  [29,] -2.13241965 -0.312172005  0.270244895  0.083977887
##  [30,] -2.25769799  0.336604248 -0.068207276 -0.107918349
##  [31,] -2.13297647  0.502856075  0.074757996 -0.048027970
##  [32,] -1.82547925 -0.422280389  0.269564311  0.239069476
##  [33,] -2.60621687 -1.787587272 -0.047070727 -0.228470534
##  [34,] -2.43800983 -2.143546796  0.082392024 -0.048053409
##  [35,] -2.10292986  0.458665270  0.169706329  0.028926042
##  [36,] -2.20043723  0.205419224  0.224688852  0.168343905
##  [37,] -2.03831765 -0.659349230  0.482919584  0.195702902
##  [38,] -2.51889339 -0.590315163 -0.019370918 -0.136048774
##  [39,] -2.42152026  0.901161067 -0.192609402 -0.009705907
##  [40,] -2.16246625 -0.267981199  0.175296561  0.007023875
##  [41,] -2.27884081 -0.440240541 -0.034778398  0.106626042
##  [42,] -1.85191836  2.329610745  0.203552303  0.288896090
##  [43,] -2.54511203  0.477501017 -0.304745527 -0.066379077
##  [44,] -1.95788857 -0.470749613 -0.308567588  0.176501717
##  [45,] -2.12992356 -1.138415464 -0.247604064 -0.150539117
##  [46,] -2.06283361  0.708678586  0.063716370  0.139801160
```

```
##  [47,] -2.37677076 -1.116688691 -0.057026813 -0.151722682
##  [48,] -2.38638171  0.384957230 -0.139002234 -0.048671707
##  [49,] -2.22200263 -0.994627669  0.180886792 -0.014878291
##  [50,] -2.19647504 -0.009185585  0.152518539  0.049206884
##  [51,]  1.09810244 -0.860091033  0.682300393  0.034717469
##  [52,]  0.72889556 -0.592629362  0.093807452  0.004887251
##  [53,]  1.23683580 -0.614239894  0.552157058  0.009391933
##  [54,]  0.40612251  1.748546197  0.023024633  0.065549239
##  [55,]  1.07188379  0.207725147  0.396925784  0.104387166
##  [56,]  0.38738955  0.591302717 -0.123776885 -0.240027187
##  [57,]  0.74403715 -0.770438272 -0.148472007 -0.077111455
##  [58,] -0.48569562  1.846243998 -0.248432992 -0.040384912
##  [59,]  0.92480346 -0.032118478  0.594178807 -0.029779844
##  [60,]  0.01138804  1.030565784 -0.537100055 -0.028366154
##  [61,] -0.10982834  2.645211115  0.046634215  0.013714785
##  [62,]  0.43922201  0.063083852 -0.204389093  0.039992104
##  [63,]  0.56023148  1.758832129  0.763214554  0.045578465
##  [64,]  0.71715934  0.185602819  0.068429700 -0.164256922
##  [65,] -0.03324333  0.437537419 -0.194282030  0.108684396
##  [66,]  0.87248429 -0.507364239  0.501830204  0.104593326
##  [67,]  0.34908221  0.195656268 -0.489234095 -0.190869932
##  [68,]  0.15827980  0.789451008  0.301028700 -0.204612265
##  [69,]  1.22100316  1.616827281  0.480693656  0.225145511
##  [70,]  0.16436725  1.298259939  0.172260719 -0.051554138
##  [71,]  0.73521959 -0.395247446 -0.614467782 -0.083006045
##  [72,]  0.47469691  0.415926887  0.264067576  0.113189079
##  [73,]  1.23005729  0.930209441  0.367182178 -0.009911322
##  [74,]  0.63074514  0.414997441  0.290921638 -0.273304557
##  [75,]  0.70031506  0.063200094  0.444537765  0.043313222
##  [76,]  0.87135454 -0.249956017  0.471001057  0.101376117
##  [77,]  1.25231375  0.076998069  0.724727099  0.039556002
##  [78,]  1.35386953 -0.330205463  0.259955701  0.066604931
##  [79,]  0.66258066  0.225173502 -0.085577197 -0.036318171
##  [80,] -0.04012419  1.055183583  0.318506304  0.064571834
##  [81,]  0.13035846  1.557055553  0.149482697 -0.009371129
##  [82,]  0.02337438  1.567225244  0.240745761 -0.032663020
##  [83,]  0.24073180  0.774661195  0.150707074  0.023572390
##  [84,]  1.05755171  0.631726901 -0.104959762 -0.183354200
##  [85,]  0.22323093  0.286812663 -0.663028512 -0.253977520
##  [86,]  0.42770626 -0.842758920 -0.449129446 -0.109308985
##  [87,]  1.04522645 -0.520308714  0.394464890  0.037084781
##  [88,]  1.04104379  1.378371048  0.685997804  0.136378719
##  [89,]  0.06935597  0.218770433 -0.290605718 -0.146653279
##  [90,]  0.28253073  1.324886147 -0.089111491  0.008876070
##  [91,]  0.27814596  1.116288852 -0.094172116 -0.269753497
##  [92,]  0.62248441 -0.024839814  0.020412763 -0.147193289
##  [93,]  0.33540673  0.985103828  0.198724011  0.006508757
##  [94,] -0.36097409  2.012495825 -0.105467721  0.019505467
##  [95,]  0.28762268  0.852873116 -0.130452657 -0.107043742
##  [96,]  0.09105561  0.180587142 -0.128547696 -0.229191812
```

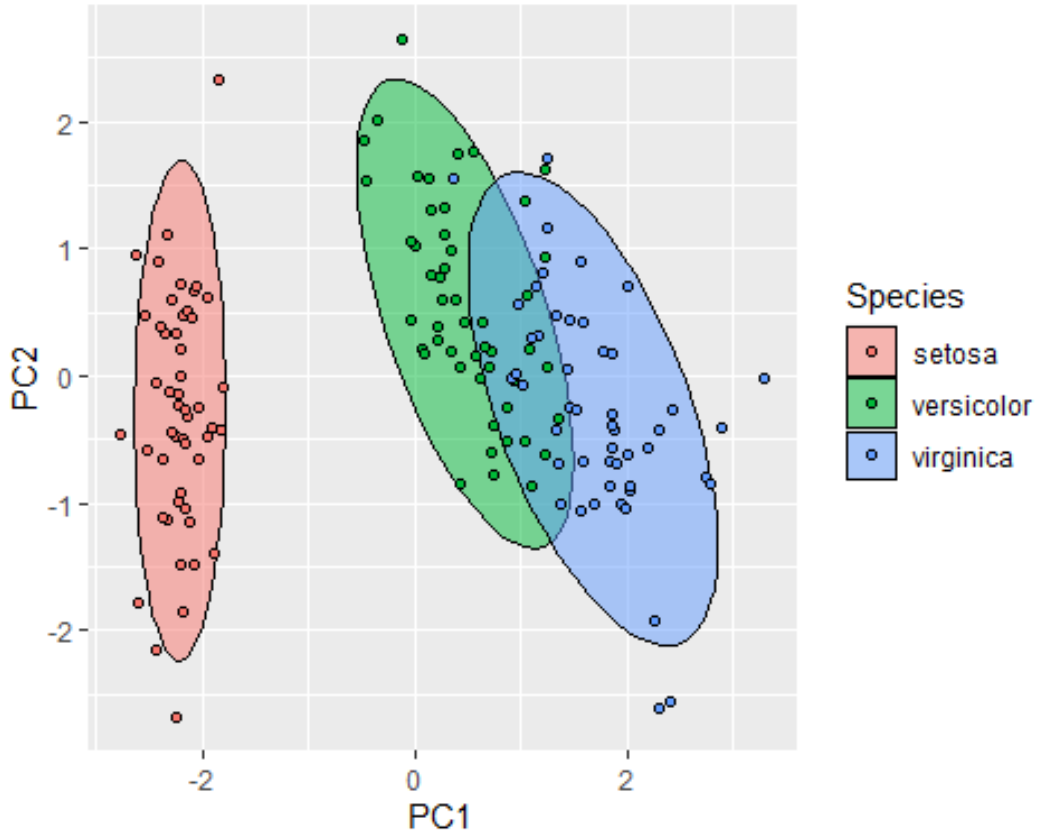
```
##  [97,]  0.22695654  0.383634868 -0.155691572 -0.132163118
##  [98,]  0.57446378  0.154356489  0.270743347 -0.019794366
##  [99,] -0.44617230  1.538637456 -0.189765199  0.199278855
## [100,]  0.25587339  0.596852285 -0.091572385 -0.058426315
## [101,]  1.83841002 -0.867515056 -1.002044077 -0.049085303
## [102,]  1.15401555  0.696536401 -0.528389994 -0.040385459
## [103,]  2.19790361 -0.560133976  0.202236658  0.058986583
## [104,]  1.43534213  0.046830701 -0.163083761 -0.234982858
## [105,]  1.86157577 -0.294059697 -0.394307408 -0.016243853
## [106,]  2.74268509 -0.797736709  0.580364827 -0.101045973
## [107,]  0.36579225  1.556289178 -0.983598122 -0.132679346
## [108,]  2.29475181 -0.418663020  0.649530452 -0.237246445
## [109,]  1.99998633  0.709063226  0.392675073 -0.086221779
## [110,]  2.25223216 -1.914596301 -0.396224508  0.104488870
## [111,]  1.35962064 -0.690443405 -0.283661780  0.107500284
## [112,]  1.59732747  0.420292431 -0.023108991  0.058136869
## [113,]  1.87761053 -0.417849815 -0.026250468  0.145926073
## [114,]  1.25590769  1.158379741 -0.578311891  0.098826244
## [115,]  1.46274487  0.440794883 -1.000517746  0.274738504
## [116,]  1.58476820 -0.673986887 -0.636297054  0.191222383
## [117,]  1.46651849 -0.254768327 -0.037306280 -0.154811637
## [118,]  2.41822770 -2.548124795  0.127454475 -0.272892966
## [119,]  3.29964148 -0.017721580  0.700957033  0.045037725
## [120,]  1.25954707  1.701046715  0.266643612 -0.064963167
## [121,]  2.03091256 -0.907427443 -0.234015510  0.167390481
## [122,]  0.97471535  0.569855257 -0.825362161  0.027662914
## [123,]  2.88797650 -0.412259950  0.854558973 -0.126911337
## [124,]  1.32878064  0.480202496  0.005410239  0.139491837
## [125,]  1.69505530 -1.010536476 -0.297454114 -0.061437911
## [126,]  1.94780139 -1.004412720  0.418582432 -0.217609339
## [127,]  1.17118007  0.315338060 -0.129503907  0.125001677
## [128,]  1.01754169 -0.064131184 -0.336588365 -0.008625505
## [129,]  1.78237879  0.186735633 -0.269754304  0.030983849
## [130,]  1.85742501 -0.560413289  0.713244682 -0.207519953
## [131,]  2.42782030 -0.258418706  0.725386035 -0.017863520
## [132,]  2.29723178 -2.617554417  0.491826144 -0.210968943
## [133,]  1.85648383  0.177953334 -0.352966242  0.099675959
## [134,]  1.11042770  0.291944582  0.182875741 -0.185721512
## [135,]  1.19845835  0.808606364  0.164173760 -0.487849130
## [136,]  2.78942561 -0.853942542  0.541093785  0.294893130
## [137,]  1.57099294 -1.065013214 -0.942695700  0.035486875
## [138,]  1.34179696 -0.421020154 -0.180271551 -0.214702016
## [139,]  0.92173701 -0.017165594 -0.415434449  0.005220919
## [140,]  1.84586124 -0.673870645  0.012629804  0.194543500
## [141,]  2.00808316 -0.611835930 -0.426902678  0.246711805
## [142,]  1.89543421 -0.687273065 -0.129640697  0.468128374
## [143,]  1.15401555  0.696536401 -0.528389994 -0.040385459
## [144,]  2.03374499 -0.864624030 -0.337014969  0.045036251
## [145,]  1.99147547 -1.045665670 -0.630301866  0.213330527
## [146,]  1.86425786 -0.385674038 -0.255418178  0.387957152
```

```
## [147,]  1.55935649  0.893692855  0.026283300  0.219456899
## [148,]  1.51609145 -0.268170747 -0.179576781  0.118773236
## [149,]  1.36820418 -1.007877934 -0.930278721  0.026041407
## [150,]  0.95744849  0.024250427 -0.526485033 -0.162533529
```

```
iris2 <- cbind(iris, iris.pca.normaldata$x)

library(ggplot2)

ggplot(iris2, aes(PC1, PC2, col = Species, fill = Species)) +
  stat_ellipse(geom = "polygon", col = "black", alpha = 0.5) +
  geom_point(shape = 21, col = "black")
```



PCA Coefficients

```
cor(iris[, 1:4], iris2[, 6:9])
```

```
##                     PC1         PC2         PC3         PC4
## Sepal.Length  0.8901688 -0.36082989  0.27565767  0.03760602
## Sepal.Width  -0.4601427 -0.88271627 -0.09361987 -0.01777631
## Petal.Length  0.9915552 -0.02341519 -0.05444699 -0.11534978
## Petal.Width   0.9649790 -0.06399985 -0.24298265  0.07535950
```