

AMCS 210 - APPLIED STATISTICS AND DATA ANALYSIS
Hernando Catequista Ombao
Applied Mathematics and Computational Sciences Program
Computer, Electrical and Mathematical Sciences & Engineering (CEMSE) Division
King Abdullah University of Science and Technology (KAUST)

HOMEWORK

2

Henrique Aparecido Laureano

Fall Semester 2017

Contents

| | |
|-------------------|-----------|
| Exercise 1 | 3 |
| (a) | 3 |
| (b) | 4 |
| Exercise 2 | 5 |
| (a) | 5 |
| (b) | 5 |
| (c) | 5 |
| (d) | 5 |
| Exercise 3 | 6 |
| (a) | 6 |
| (b) | 7 |
| Exercise 4 | 7 |
| Exercise 5 | 16 |
| (a) | 16 |
| (b) | 16 |
| (c) | 17 |

| | |
|-------------------|-----------|
| Exercise 6 | 17 |
| (a) | 18 |
| (b) | 18 |

Exercise 1

A politician running for office is interested in estimating the proportion among legal residents of the state of California who support the DREAMER's act (which we denote as π). An organization was instructed to conduct a poll with the constraint that the estimator should be within a tolerance limit of 0.05.

Suppose that the true population proportion of supporters is $\pi = 0.65$. The organization is now at a planning stage to determine the desired sample size so that there is only a slim chance of 10% that an estimator (sample proportion) falls outside of the designated tolerance limit (i.e., it falls outside of 0.60 and 0.70).

(a)

Conduct a simulation study to determine if a sample size of $n = 200$ respondents will be sufficient to meet the target? As a guide to approaching this problem: (i.) simulate at least $B = 10.000$ samples each of size $n = 200$ from a binomial distribution; (ii.) for each sample record the sample proportion; (iii.) determine the proportion (out $B = 10.000$ samples) of sample proportion that fall within the designated tolerance limit.

Solution:

```
# <code r> ===== #
## defining some variables
n <- 200 # sample size
B = 1e4 # number of replications
p <- .65 # true proportion
tol <- .05 # tolerance level
in_inter <- numeric(B) # creating empth object of size B

## simulation study code
for (i in 1:B){
  samp <- rbinom(1, n = n, p = p) # simulating samples from a binomial dist.
  prop <- mean(samp) # sample proportion
  abs_samp <- abs(prop - p) # difference to the tolerance level
  in_inter[i] <- ifelse(abs_samp <= tol, "in", "out") # if is in or out
}
# proportion of sample proportion that fall within (or out) the tol. level
prop.table(table(in_inter))
# </code r> ===== #

in_inter
  in      out
0.8622 0.1378
```

The proportion is of 14%, bigger than the desired proportion of 10%.

(b)

If the sample size of $n = 200$ does not satisfy the requirement above continue with procedure of finding the smallest sample size that would satisfy the tolerance limit.

Solution:

```
# <code r> ===== #
final_prop <- prop.table(table(in_inter)) ; prop_out <- final_prop[[2]]
while (final_prop[[2]] > .1){
  for (i in 1:B){
    samp <- rbinom(1, n = n + 1, p = p)
    prop <- mean(samp) ; abs_samp <- abs(prop - p)
    in_inter[i] <- ifelse(abs_samp <= tol, "in", "out")
  }
  final_prop <- prop.table(table(in_inter))
  prop_out[length(prop_out)+1] <- final_prop[[2]] ; n <- n + 1}
library(latticeExtra)
xyplot(prop_out ~ 200:n, type = c("h", "p"), pch = 16
      , xlab = "Sample size", ylab = "Tolerance limit"
      , main = paste0(
        "Smallest sample size: ", n, " (tolerance limit: ", min(prop_out), ")")
      , scales = list(x = list(at = c(200, n)))
      , panel = function(...){
        panel.abline(h = .1, col = 2, lty = 2)
        panel.xyplot(...)
        panel.segments(n, 0, n, min(prop_out), col = 2, lwd = 2)
        panel.points(n, min(prop_out), col = 2, pch = 16)})
# </code r> ===== #
```

Smallest sample size: 233 (tolerance limit: 0.0985)

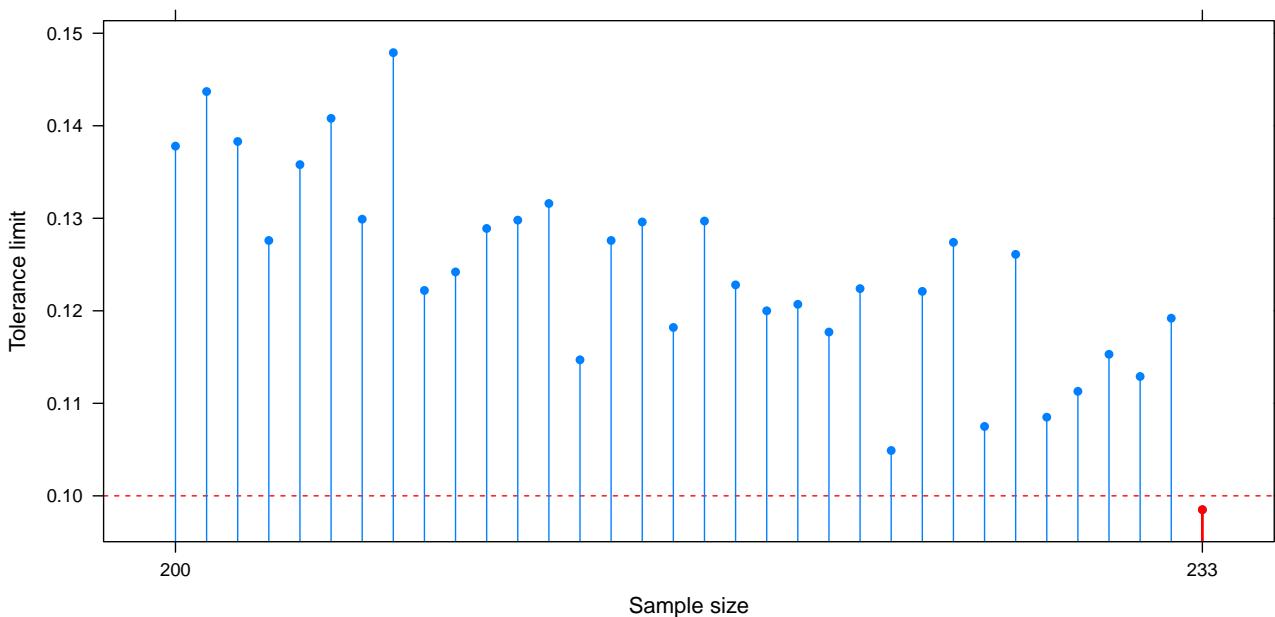


Figure 1: Sample sizes vs. tolerance limits.

Exercise 2

Exercises on calculating binomial probabilities. Let X be a binomial random variable with $n = 5$ and probability parameter $\pi = 0.3$. Think of this as counting the number of heads obtained by tossing $n = 5$ identical coins each of which has the probability of $\pi = 0.3$ that it lands in heads.

(a)

Enumerate the elements of the sample space of X .

Solution:

$$\Omega = \{0, 1, 2, 3, 4, 5\}.$$

(b)

Obtain the table of probability mass function, i.e., compute the probabilities $\mathbb{P}(X = x)$ for each x in the sample space.

Solution:

$$\mathbb{P}(X = x) = \binom{n}{x} \pi^x (1 - \pi)^{n-x} = \binom{5}{x} 0.3^x (0.7)^{5-x}.$$

| x | $\mathbb{P}(X = x)$ |
|---|---------------------|
| 0 | 0.16807 |
| 1 | 0.36015 |
| 2 | 0.3087 |
| 3 | 0.1323 |
| 4 | 0.02835 |
| 5 | 0.00243 |

(c)

Compute $\mathbb{P}(X \geq 4)$.

Solution:

$$\mathbb{P}(X \geq 4) = \mathbb{P}(X = 4) + \mathbb{P}(X = 5) = 0.02835 + 0.00243$$

$$\boxed{\mathbb{P}(X \geq 4) = 0.03078.}$$

(d)

Compute $\mathbb{P}(X < 3)$.

Solution:

$$\mathbb{P}(X < 3) = 1 - \mathbb{P}(X \geq 3) = 1 - [\mathbb{P}(X = 3) + \mathbb{P}(X \geq 4)] = 1 - [0.1323 + 0.03078] = 1 - 0.16308$$

$$\boxed{\mathbb{P}(X < 3) = 0.83692.}$$

Exercise 3

Exercises on calculating probabilities for the normal distribution. Some of these require the use of the standard normal probability table which has been uploaded in the subfolder "Admin" in the class dropbox.

(a)

Suppose that the systolic blood pressure (SBP) among white teens follows a normal distribution with mean $\mu = 120$ units (mm Hg) and standard deviation $\sigma = 4$ units.

(i.) What are the first and third quartile SBP values in this population?

Solution:

(ii.) What is the 90-th percentile SBP value?

Solution:

(iii.) Use the standard normal table to calculate the proportion of teens with SBP between 112 and 126 units.

Solution:

(iv.) A teen was randomly selected from the population. What is the probability that this teen has SBP that is greater than 130 units?

Solution:

(v.) An investigator randomly selected 5 teens. What is the probability that none of them has SBP that exceeds 130 units?

Solution:

(vi.) Again on the 5 teens: what is the probability that exactly 1 has SBP that exceeds 130 units.

Solution:

(b)

A graduate program will admit only students who score on the top 90-th percentile in an international examination. There is some complication in the admissions process because the grading scheme for the examination changed in 2016. Prior to 2016, the scores ranged from 0 to 800. From 2016 onwards the scores were recalibrated so that they range from 0 to 150. Suppose that the pre-2016 scores followed a normal distribution with mean 600 and variance of 50. From 2016 onwards the distribution remained normal but the mean is 120 and the variance is 15. One applicant who took the test in 2015 scored 700 (out of 800) and another who took the test in 2017 scored 130 (out of 200). Check if either of these applicants should be automatically denied admission based on the examination scores.

Solution:

Exercise 4

Download the “wdbc” data set. Provide a bar graph for the discrete variable, and scatter plots for each pair of continuous variables. Provide the box plots of continuous variables for each level of “Diagnosis”. In one paragraph, discuss your findings based on these graphs.

Solution:

```
# <code r> ===== #
library("kdevine") ; data(wdbc)

barchart(wdbc$diagnosis, col = "#0080ff", xlab = "Frequency", xlim = c(0, 410)
      , scales = list(x = list(draw = FALSE)
                      , y = list(labels = c("Benign", "Malignant")))
      , border = "transparent", main = "Diagnosis"
      , panel = function(...){
        args <- list(...)
        panel.text(args$x, args$y, pos = 4
                   , paste0(args$x, " (", round(prop.table(args$x),3)*100,"%)"))
        panel.barchart(...)})
```

</code r> =====

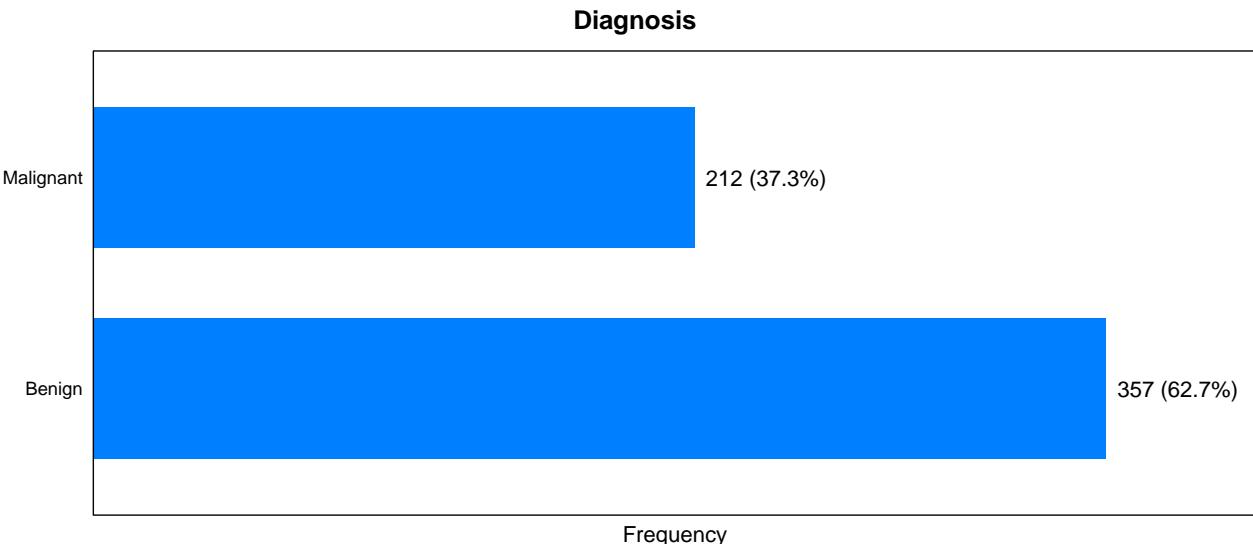


Figure 2: Frequency and percentage for each level of "Diagnosis".

This dataset contain measurements on cells in suspicious lumps in a women's breast. Variables are computed from a digitized image of a fine needle aspirate (FNA) of a breast mass. They describe characteristics of the cell nuclei present in the image. All samples are classsified as either *benign* or *malignant*.

Ten real-valued variables are computed for each cell nucleus.

The mean, standard error, and "worst" or largest (mean of the three largest values) of these variables were computed for each image, resulting in 30 variables.

This breast cancer database was obtained from the University of Wisconsin Hospitals, Madison from Dr. William H. Wolberg.

Thus, we provide the scatter plots for each pair of variables divided by the mean, standard error and "worst" values, resulting in this way in three scatter plot matrices.

```
# <code r> ===== #
panel.cor <- function(x, y, ...){
  usr <- par("usr")
  on.exit(par(usr))
  par(usr = c(0, 1, 0, 1))
  r <- abs(cor(x, y))
  txt <- format(c(r, 0.123456789), digits = 2)[1]
  text(0.5, 0.5, txt, cex = .8/strwidth(txt))
}
rotulos <- tm::removeWords(names(wdbc[2:11]), "mean ")
```

```
rotulos[c(5:6, 8, 10)] <- c("smooth", "compact", "concave", "fractal d.")

pairs(wdbc[2:11]
      , pch = 16
      , gap = .25
      , las = 1
      , upper.panel = panel.cor
      , col = c("#0080ff", "gray30")[unclass(wdbc$diagnosis)]
      , labels = rotulos
      , font.labels = 2
      , main = "Mean")
# </code r> ===== #
```

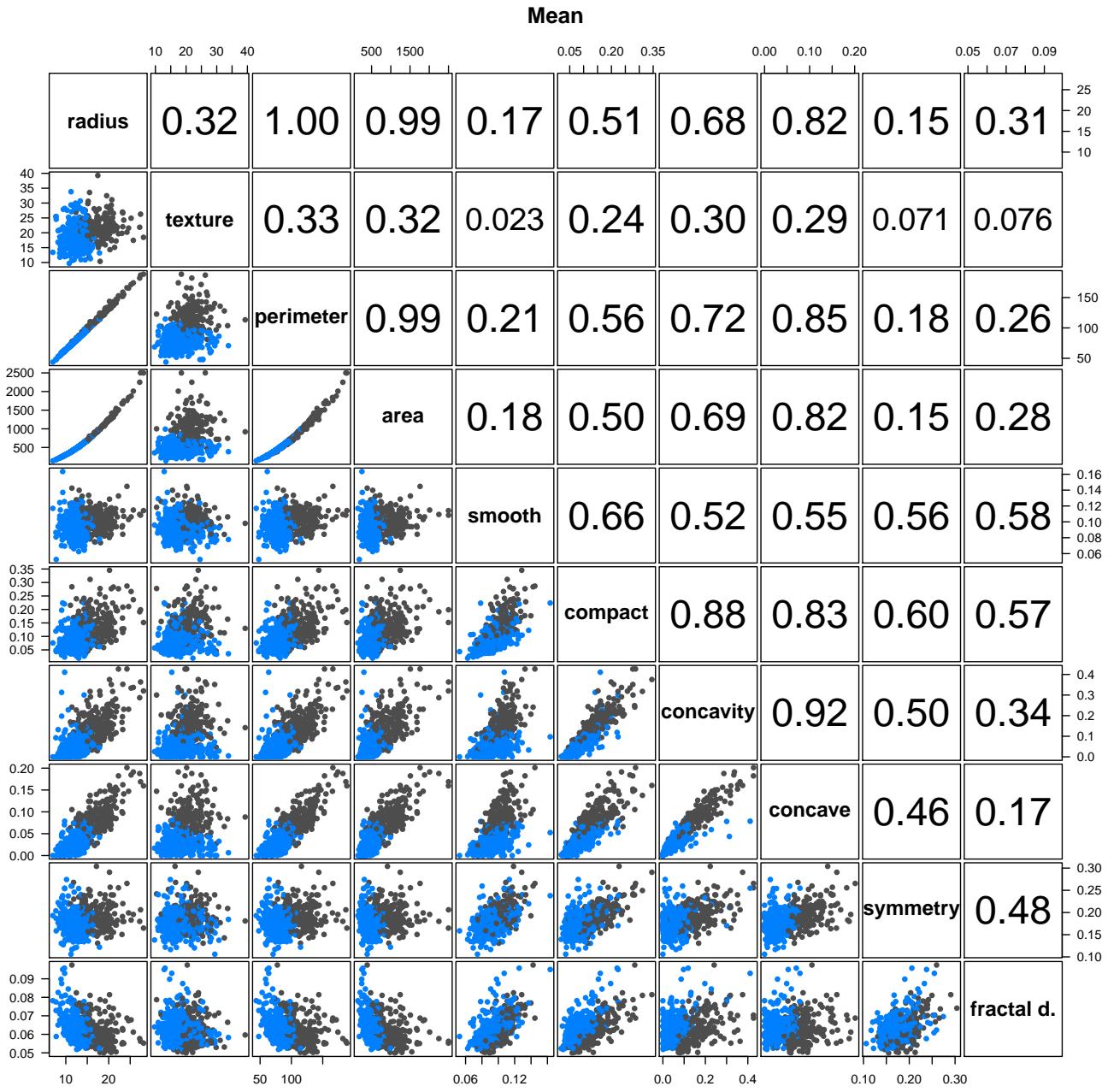


Figure 3: Scatter plots for each pair of mean variables in the lower triangular part of the matrix, in the upper triangular part we have the respective correlations between the variables. In blue we have the corresponding observations to the benign diagnosis and in gray the corresponding observations to the malignant diagnosis.

```
# <code r> ===== #
rotulos <- tm::removeWords(names(wdbc[12:21]), "worst")
rotulos[c(5:6, 8, 10)] <- c("smooth", "compact", "concave", "fractal d.")

pairs(wdbc[12:21], pch = 16, gap = .25, las = 1, upper.panel = panel.cor
      , col = c("#0080ff", "gray30")[unclass(wdbc$diagnosis)]
      , labels = rotulos, font.labels = 2, main = '"Worst"')
```

```
# </code r> ====== #
```

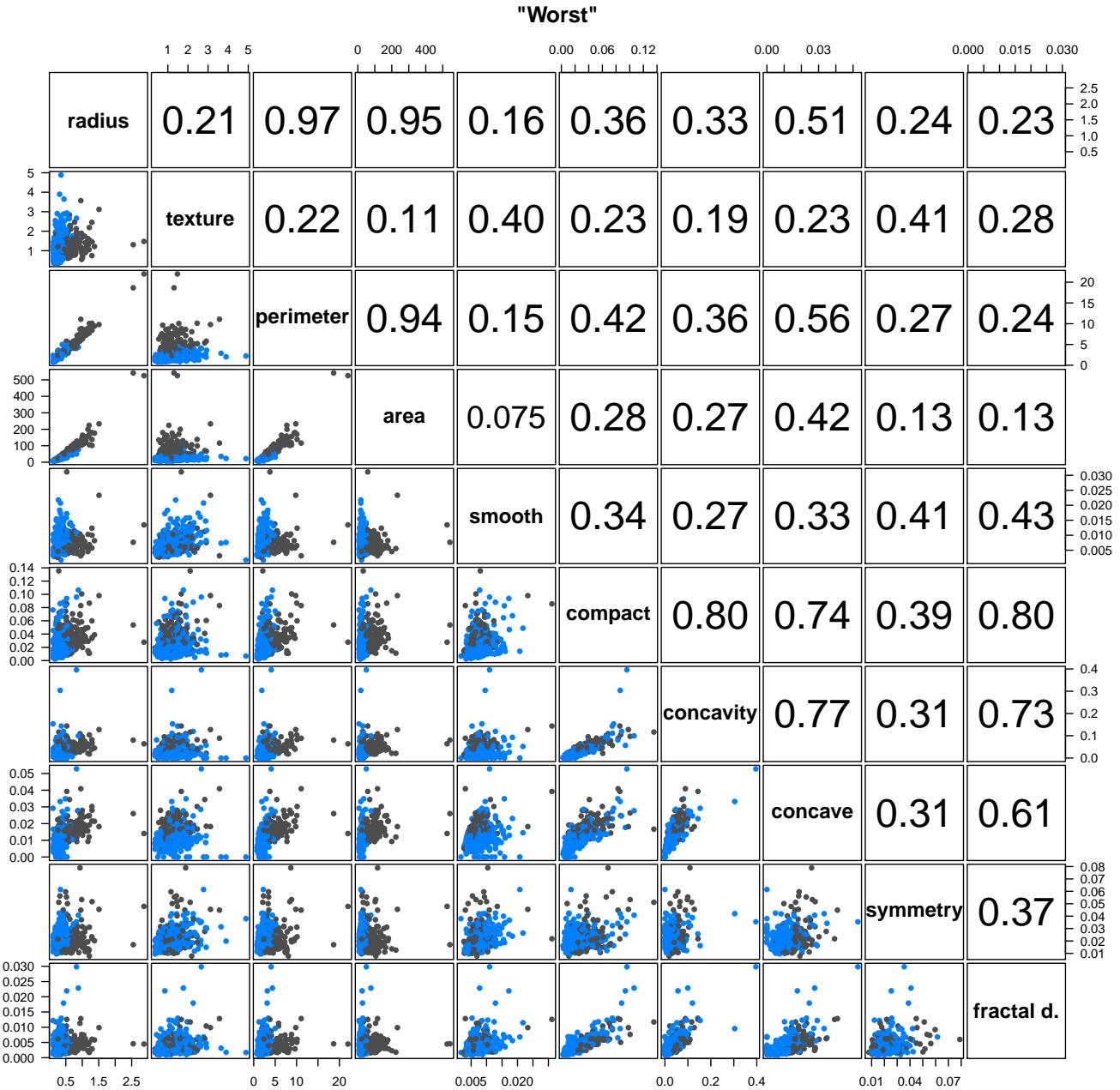


Figure 4: Scatter plots for each pair of "worst" variables in the lower triangular part of the matrix, in the upper triangular part we have the respective correlations between the variables. In blue we have the corresponding observations of the benign diagnosis and in gray the corresponding observations of the malignant diagnosis.

```
# </code r> ====== #
rotulos <- tm::removeWords(names(wdbc[22:31]), "sd ")
rotulos[c(5:6, 8, 10)] <- c("smooth", "compact", "concave", "fractal d.")
```

```

pairs(wdbc[22:31], pch = 16, gap = .25, las = 1, upper.panel = panel.cor
      , col = c("#0080ff", "gray30")[unclass(wdbc$diagnosis)]
      , labels = rotulos, font.labels = 2, main = "Standard error")
# </code r> ===== #

```

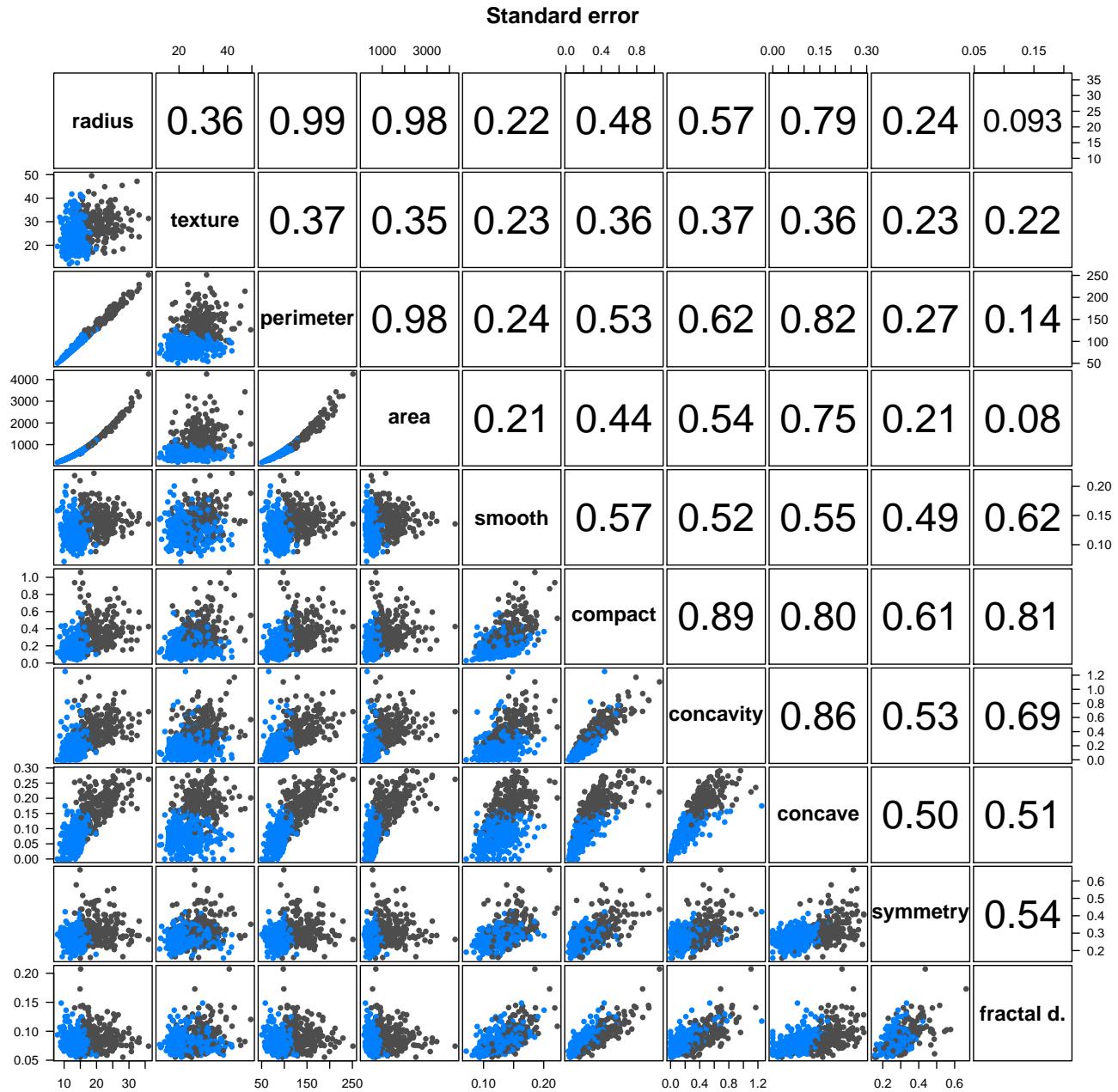


Figure 5: Scatter plots for each pair of standard error variables in the lower triangular part of the matrix, in the upper triangular part we have the respective correlations between the variables. In blue we have the corresponding observations to the benign diagnosis and in gray the corresponding observations to the malignant diagnosis.

Box plots:

```
# <code r> ===== #
wdbc_mean <- reshape2::melt(wdbc[1:11], id.vars = "diagnosis")
levels(wdbc_mean$diagnosis) <- c("Benign", "Malignant")
levels(wdbc_mean$variable) <- tm::removeWords(levels(wdbc_mean$variable), "mean ")

bwplot(value ~ diagnosis | variable, wdbc_mean
, layout = c(4, 3), scales = list(y = list(relation = "free", rot = 0))
, ylab = NULL, strip = strip.custom(bg = "white"), pch = "|"
, main = "Mean"
, par.settings = list(
  box.rectangle = list(
    col = c("#0080ff", "gray60"), fill = c("#0080ff", "gray60")
    , alpha = .6, border = "transparent"
    , box.umbrella = list(col = c("#0080ff", "gray60"))
    , plot.symbol = list(col = "red", pch = 16, alpha = .6)))
# </code r> ===== #
```

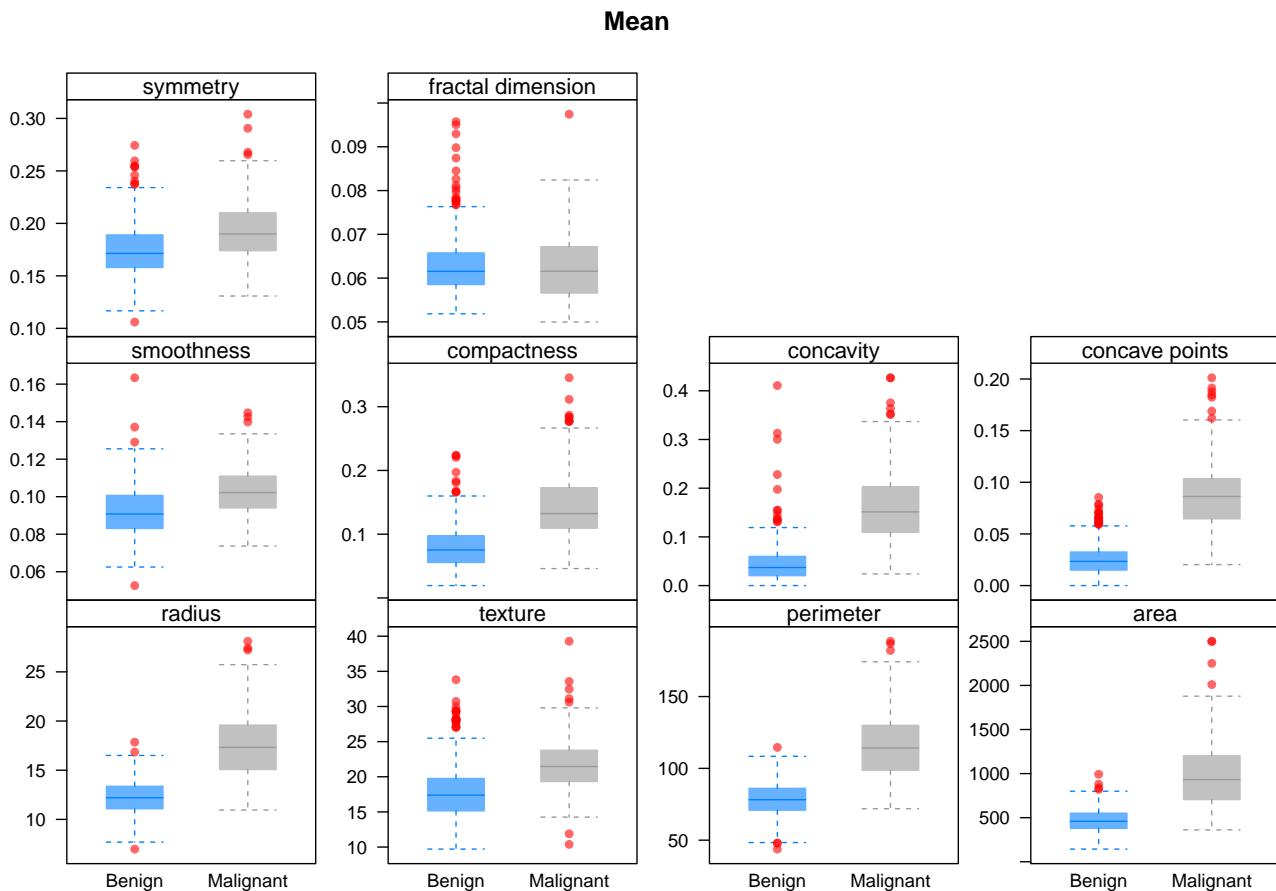


Figure 6: Box plots for each mean variable divided by "Diagnosis".

```

# <code r> ===== #
wdbc_worst <- reshape2::melt(wdbc[c(1, 12:21)], id.vars = "diagnosis")
levels(wdbc_worst$diagnosis) <- c("Benign", "Malignant")
levels(wdbc_worst$variable) <-
  tm::removeWords(levels(wdbc_worst$variable), "worst ")

bwplot(value ~ diagnosis | variable, wdbc_worst
  , layout = c(4, 3), scales = list(y = list(relation = "free", rot = 0))
  , ylab = NULL, strip = strip.custom(bg = "white"), pch = "|"
  , main = '"Worst"'
  , par.settings = list(
    box.rectangle = list(
      col = c("#0080ff", "gray60"), fill = c("#0080ff", "gray60")
      , alpha = .6, border = "transparent")
    , box.umbrella = list(col = c("#0080ff", "gray60"))
    , plot.symbol = list(col = "red", pch = 16, alpha = .6)))
# </code r> ===== #

```

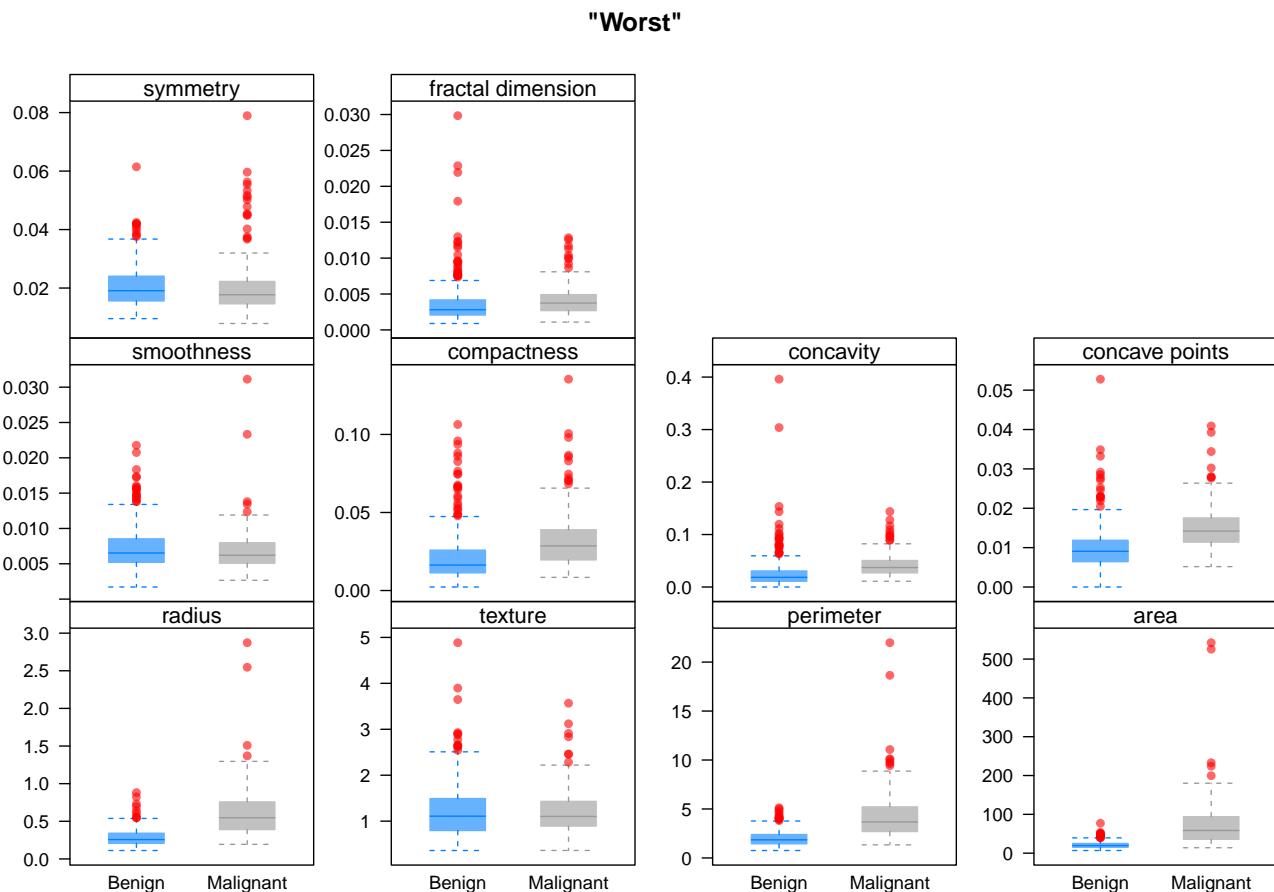


Figure 7: Box plots for each "worst" variable divided by "Diagnosis".

```
# <code r> ===== #
wdbc_sd <- reshape2::melt(wdbc[c(1, 22:31)], id.vars = "diagnosis")
levels(wdbc_sd$diagnosis) <- c("Benign", "Malignant")
levels(wdbc_sd$variable) <- tm::removeWords(levels(wdbc_sd$variable), "sd ")

bwplot(value ~ diagnosis | variable, wdbc_sd
       , layout = c(4, 3), scales = list(y = list(relation = "free", rot = 0))
       , ylab = NULL, strip = strip.custom(bg = "white"), pch = "|"
       , main = "Standard error"
       , par.settings = list(
         box.rectangle = list(
           col = c("#0080ff", "gray60"), fill = c("#0080ff", "gray60")
           , alpha = .6, border = "transparent")
         , box.umbrella = list(col = c("#0080ff", "gray60"))
         , plot.symbol = list(col = "red", pch = 16, alpha = .6)))
# </code r> ===== #
```

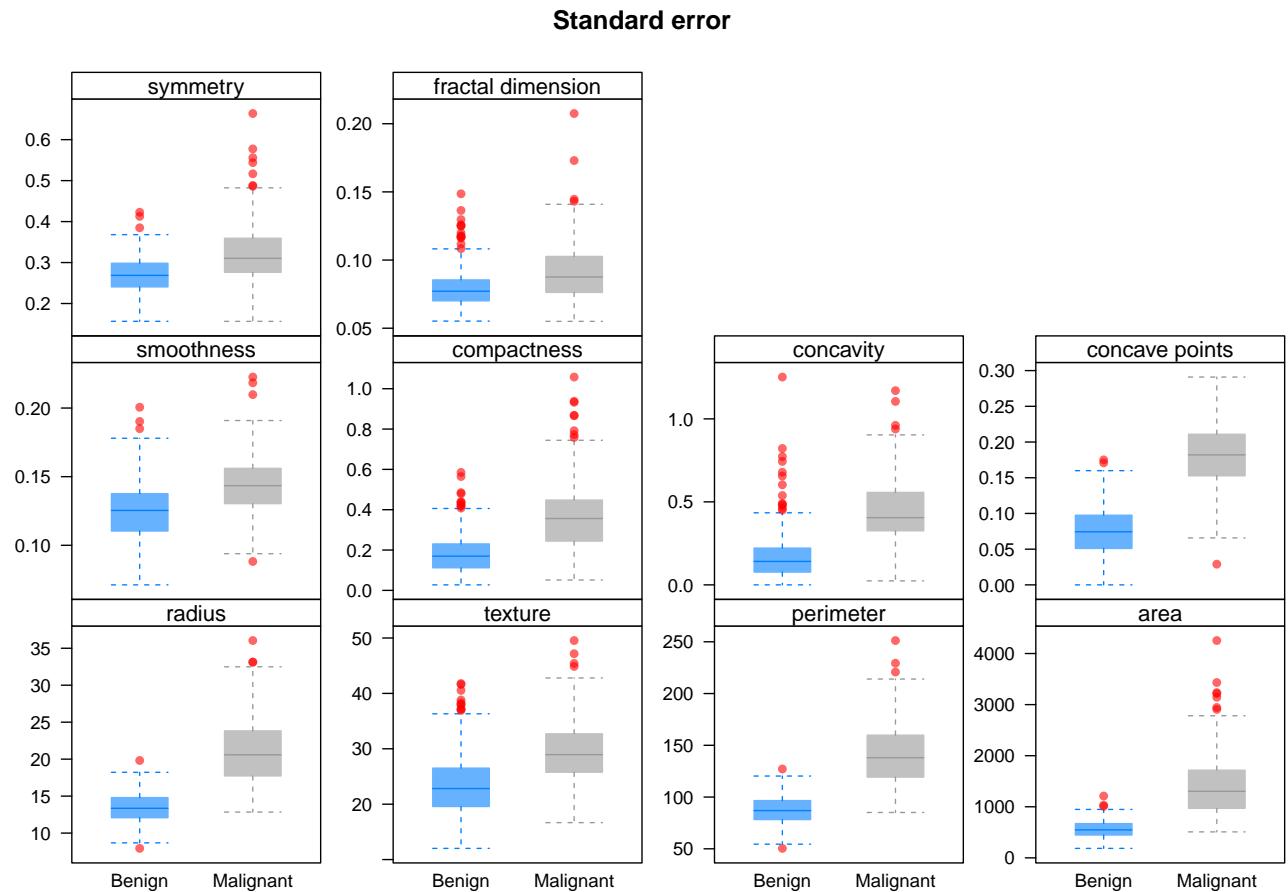


Figure 8: Box plots for each standard error variable divided by "Diagnosis".

Approximately 2/3 of the patients were with the exam classified as benign. When we look to the mean variables, three pairs present a correlation (linear correspondence) extremely close to 1. Between this ten variables we see every behavior types. Relations with a very high correlation,

with a medium correlation and with a very small correlation. In general, the same behavior is seen with the same variables when we looked to the "worst" and standard error variables. We can highlight as very high correlations the relations between the variables area and perimeter, radius and perimeter, and radius and area. As a very small correlation we can highlight the relations between the variables texture and symmetry, texture and fractal dimension, area and symmetry, and area and fractal dimension. When we looked to the box plots, in general, for all the ten variables in the three different measure types, the biggest values are present in the patients classified as malignant.

Exercise 5

Consider this dataset derived from the Framingham Heart Study where one of the goals was to study possible links between high systolic blood pressure (SBP) and coronary heart disease (CHD). Participants with $SBP \geq 165$ mm Hg were put in the "high" SBP category.

| | CHD | No CHD |
|------------|-----|--------|
| High SBP | 144 | 62 |
| Normal SBP | 120 | 419 |

(a)

Marginal proportions. From the table, what is the proportion of participants who had CHD? What is the proportion of participants who had high SBP?

Solution:

$$CHD = 144 + 120 = 264, \quad NoCHD = 62 + 419 = 481, \quad n = CHD + NoCHD = 745$$

Proportion of participants who had CHD: $CHD/n = 264/745 = 0.3543624$ (35%).

$$HiSBP = 144 + 62 = 206, \quad NorSBP = 120 + 419 = 539, \\ n = CHD + NoCHD = HiSBP + NorSBP = 745$$

Proportion of participants who had high SBP: $HiSBP/n = 206/745 = 0.2765101$ (28%).

(b)

Conditional proportions. Among the participants with high SBP, what is the proportion of those who also have CHD? Among the participants with normal SBP, what is the proportion of those who also have CHD? Does this provide some evidence of a link between elevated systolic blood pressure and coronary heart disease? Can one now claim that elevated systolic blood pressure causes coronary heart disease?

Solution:

Among the participants with high SBP, the proportion of those who also have CHD:
 $CHD/HiSBP = 144/206 = 0.6990291$ (70%).

Among the participants with normal SBP, the proportion of those who also have CHD:
 $CHD/NorSBP = 120/539 = 0.2226345$ (22%).

Does this provide some evidence of a link between elevated systolic blood pressure and coronary heart disease? Yes. Because in the patients with normal SBP the proportion with CHD is 22 percent, almost 1/5, while in the patients with high SBP the proportion with CHD is 70 percent, much higher.

Can one now claim that elevated systolic blood pressure causes coronary heart disease? No. With this descriptive analysis we can see a possible correlation between high SBP and CHD, but this not implies in causality. we don't have enough information to claim this type of result. Correlation is different form causality.

(c)

Odds and odds ratios. Compute the odds of having CHD among the high SBP group. Compute the odds of having CHD among the normal SBP group. Compute the odds ratio of having CHD for the high SBP vs normal SBP groups.

Solution:

Odds of having CHD among the high SBP group:

$$\frac{144/206}{1 - 144/206} = 2.322581.$$

Odds of having CHD among the normal SBP group:

$$\frac{120/539}{1 - 120/539} = 0.2863962.$$

Odds ratio of having CHD for the high SBP vs normal SBP groups:

$$\frac{2.322581}{0.286396} = 8.109678.$$

The odds of having CHD for the high SBP groups is 8.11 times of the odds of CHD for the normal SBP group.

Exercise 6

The beetle mortality data. Groups of beetles were exposed to varying doses of toxins and the number of deaths (y_{total}) out of the total exposure (n_{total}) were recorded. Enter the variables in R:

```

dose = c(1.69, 1.72, 1.75, 1.78, 1.81, 1.84, 1.86, 1.88)
ntotal = c(59, 60, 62, 56, 63, 59, 62, 60)
ytotal = c(6, 13, 18, 28, 52, 53, 61, 60)

# <code r> ===== #
dose <- c(1.69, 1.72, 1.75, 1.78, 1.81, 1.84, 1.86, 1.88)
ntotal <- c(59, 60, 62, 56, 63, 59, 62, 60)
ytotal <- c(6, 13, 18, 28, 52, 53, 61, 60)
# </code r> ===== #

```

(a)

Calculate the proportion of deaths for each dose-group.

Solution:

```

# <code r> ===== #
rbind(dose, "death proportion" = round(ytotal/ntotal, 2))
# </code r> ===== #

[,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
dose      1.69 1.72 1.75 1.78 1.81 1.84 1.86 1.88
death proportion 0.10 0.22 0.29 0.50 0.83 0.90 0.98 1.00

```

(b)

Plot the proportion of deaths against dose. Describe the trend: is it increasing/ decreasing, is there an asymptote feature?

Solution:

```

# <code r> ===== #
xyplot(ytotal/ntotal ~ dose, type = c("p", "l")
       , pch = 19, lwd = 1.5, xlab = "Dose", ylab = "Proportion of deaths"
       , scales = list(x = list(at = dose)))
       , panel = function(...){
         panel.abline(v = dose, h = seq(.2, 1, .2), col = "gray70")
         panel.xyplot(...)})
# </code r> ===== #

```

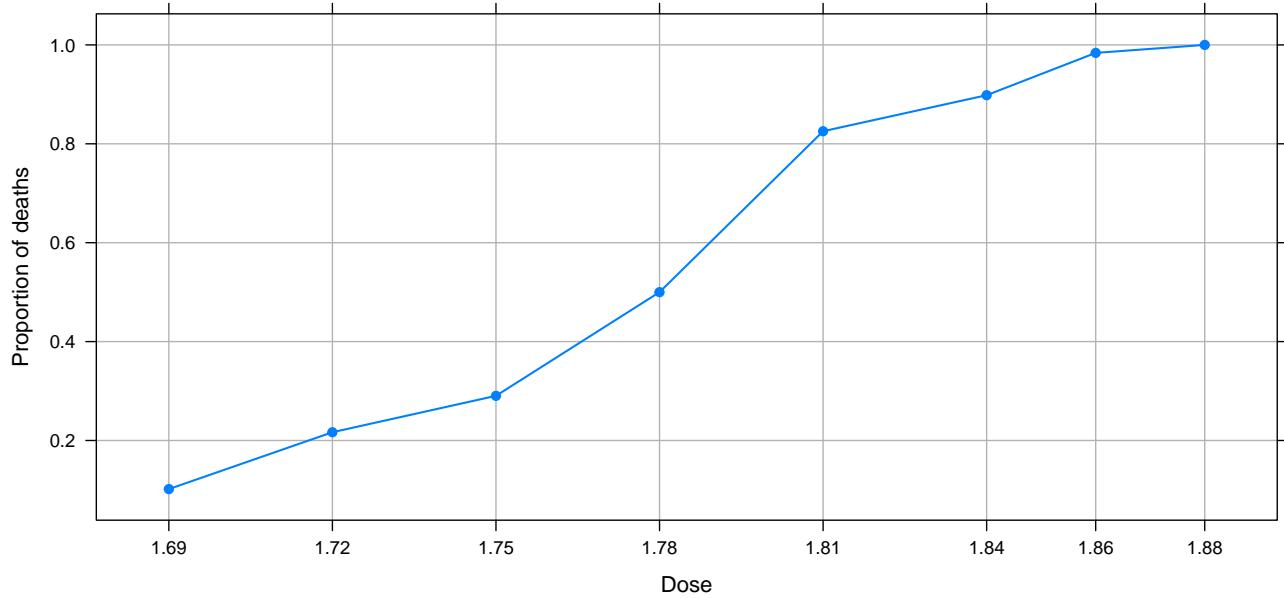


Figure 9: Proportion of deaths against dose.

The trend is increasing. For small doses the proportions are very close to zero, with the biggest doses the proportions are very close to one. With the last dose we have a proportion equal to one, the maximum possible. What's means that with the biggest dose all the beetles are dead. ■