HW 2

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Problem 1

Using the following dataset where the class attribute is "Treatment Applied" and using the Decision Tree Induction Algorithm 3.1 given on Page 137 in the textbook, answer the following questions:

a)

```
# First declare the data
horse.surgery <- c(0,1,1,0,0,1,1,0,0,0,1,1)
horse.pulse <- c(92, 88, 64, 48, 76, 76, 88, 48, 92, 48, 64, 64)
adbominal.distension <- c("None", "Severe", "Severe", "Slight", "Slight", "None", "Severe", "Severe", "S
treat.applied <- c(3, 2, 2, 1, 4, 1, 3, 1, 4, 1, 1, 4)
treat.applied <- paste("Level", treat.applied)
horse.data <- data.frame(horse.surgery, horse.pulse, adbominal.distension, treat.applied)

# Now declare a function which will calculate the entropy of a given set of classes
calc.entropy <- function(tableVal){
  ## This function requires a table of the classes to be classified
  freqs = tableVal/sum(tableVal)
  out.val <- -sum(ifelse(freqs > 0, freqs * log(freqs), 0))
  out.val <- out.val / log(2)
  return(out.val)
}

## Now calculate the entire dataset entropy
entropy.treatment <- calc.entropy(table(horse.data$treat.applied)) # Total dataset entropy == 1.887919

### First explore first round cuts
## First calculate surgery here
entropy.treatment.surgery.no <- calc.entropy(table(horse.data$treat.applied[which(horse.data$horse.surge
entropy.treatment.surgery.yes <- calc.entropy(table(horse.data$treat.applied[which(horse.data$horse.surg
## Now calculate the weighted difference
weigthed.entropy.step1.1 <- (6/12 * entropy.treatment.surgery.no) + (6/12 * entropy.treatment.surgery.ye
entropy.gain1.1 <- entropy.treatment - weigthed.entropy.step1.1
## Information gain for surgery == .1991966

## Now try information gain for abdominal distension
entropy.treatment.distenssion.none <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adbom
entropy.treatment.distenssion.slight <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adb
entropy.treatment.distenssion.severe <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adb
## Now calculate the weighted difference
weigthed.entropy.step1.2 <- (2/12 * entropy.treatment.distenssion.none) + (5/12 * entropy.treatment.dist
```

```
entropy.gain1.2 <- entropy.treatment - weigthed.entropy.step1.2
## Information gain here ==.5158857


## Now explore HR with various cutoff points
for(i in unique(horse.data$horse.pulse)){
  horse.data$hrBin <- 0
  horse.data$hrBin[horse.data$horse.pulse>i] <- 1
  entropy.treatment.hr.bin.0 <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hrBin==0)]
  entropy.treatment.hr.bin.1 <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hrBin==1)]
  weigthed.entropy.step1.4 <- (sum(horse.data$hrBin==0)/12 * entropy.treatment.hr.bin.0) + (sum(horse.da
  entropy.gain1.4 <- entropy.treatment - weigthed.entropy.step1.4
  #print(paste(i, ":", entropy.gain1.4))
}
# [1] "92 : NA"
# [1] "88 : 0.253781796468065"
# [1] "64 : 0.302956001949977"
# [1] "48 : 0.406715376769688"
# [1] "76 : 0.522055208874201"

## The first step will be to create a binary variable using heartrate with a cutoff of > 76
## If HR is lower than 76 --> treatment group 1

horse.data$hrBin <- 0
horse.data$hrBin[horse.data$horse.pulse>76] <- 1

## First calculate the total entropy of the pulse <= 76 cohort
entropy.treatment.low.hr <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hrBin==0)]))

## Now calculate entropy for surgery
entropy.treatment.low.hr.surgery.no <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hrBi
entropy.treatment.low.hr.surgery.yes <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hrB

## Now calculate the weighted difference
weigthed.entropy.step2.1 <- (4/8 * entropy.treatment.low.hr.surgery.no) + (4/8 * entropy.treatment.low.h
entropy.gain2.1 <- entropy.treatment.low.hr - weigthed.entropy.step2.1
## Information gain for surgery == 0.1431559

## Now try information gain for abdominal distension
entropy.treatment.low.none <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adbominal.dis
entropy.treatment.low.slight <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adbominal.d
entropy.treatment.low.severe <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adbominal.d

## Now calculate the information gain
weigthed.entropy.step2.2 <- (1/8 * entropy.treatment.low.none) + (5/8 * entropy.treatment.low.slight) +
entropy.gain2.2 <- entropy.treatment.low.hr - weigthed.entropy.step2.2
## Information gain for surgery == 0.4419508

## The second step for those horses who have lower heart rate will be to flag for abdominal distension:
# for those with slight & none --> level 1 treatment
# for those with Severe abdominal distension --> level 2 treatment

## Now run through the same procedure for the high hr observations
```

```
## First calculate the total entropy of the pulse > 76 cohort
entropy.treatment.high.hr <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hrBin==1)]))

## Now calculate entropy for surgery
entropy.treatment.high.hr.surgery.no <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hrB
entropy.treatment.high.hr.surgery.yes <- calc.entropy(table(horse.data$treat.applied[which(horse.data$hr

## Now calculate the weighted difference
weigthed.entropy.step2.1 <- (2/4 * entropy.treatment.high.hr.surgery.no) + (2/4 * entropy.treatment.high
entropy.gain2.1 <- entropy.treatment.low.hr - weigthed.entropy.step2.1
## Information gain for surgery == 0.5

## Now try information gain for abdominal distension
entropy.treatment.high.none <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adbominal.di
entropy.treatment.high.slight <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adbominal
entropy.treatment.high.severe <- calc.entropy(table(horse.data$treat.applied[which(horse.data$adbominal

## Now calculate the information gain
weigthed.entropy.step2.2 <- (1/4 * entropy.treatment.high.none) +  (3/4 * entropy.treatment.high.severe)
entropy.gain2.2 <- entropy.treatment.low.hr - weigthed.entropy.step2.2
## Information gain for distension == 0.3112781

## The second step for those horses who have higher heart rate will be to flag for surgery:
# for those with surgery --> level 2 treatment
# for those without surgery --> level 4 treatment
```

Final tree for part a:

Heart rate <=76

| Distension == none : treatment level 1

| Distension == slight: treatment level 1

| Distension == severe: treatment level 2

Heart rate >76

| Surgery == Yes: treatment level 2

| Surgery == No : Treatment level 4

Problem 2

1)

The Iterative Dichotomiser 3 (ID3) algorithm and also the Classification and Regression Tree (CART) are two tree based approaches that are used to classify and for the latter cases they can also be used for regression. The ID3 approach stems from work performed in the 1980's by J.R. Quinlan whom introduced the technique as a method to classify noisy and incomplete data (1985). The CART approach was contemporaneously developed by Breiman as an alternative to parametric regression techniques which were the predominant analytic technique of the time period (1984).

2)

a)

```r
# Load the data
in.data <- read.csv('../Data/wine.csv')
# Now make a plot of the Magnesium; Color Intensity; and Malic Acid
out.plot.standard <- in.data[,c("Magnesium", "Color_intensity", "Malic_acid")] %>%
  mutate(across(where(is.numeric), scale)) %>%
  reshape2::melt(.) %>%
  ggplot(., aes(x=variable, y=value)) +
  geom_boxplot() +
  theme_bw() +
  ggtitle("z-score values boxplot")
```

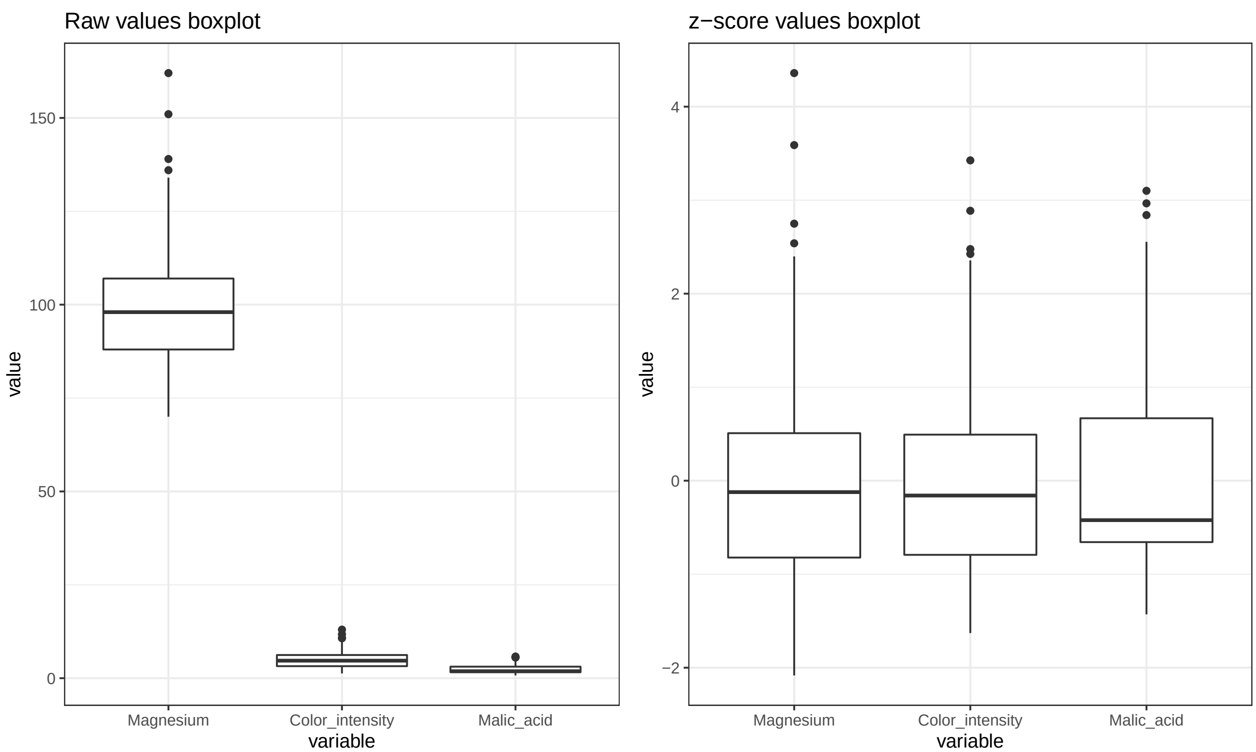
```
No id variables; using all as measure variables
```

```
Warning: attributes are not identical across measure variables; they will be
dropped
```

```r
out.plot.raw <- in.data[,c("Magnesium", "Color_intensity", "Malic_acid")] %>%
  #mutate(across(where(is.numeric), scale)) %>%
  reshape2::melt(.) %>%
  ggplot(., aes(x=variable, y=value)) +
  geom_boxplot() +
  theme_bw() +
  ggtitle("Raw values boxplot")
```

```
No id variables; using all as measure variables
```

```r
multiplot(out.plot.raw, out.plot.standard, cols = 2)
```



b)

It appears all three of the plotted variables have observations that are greater than 1.5 times the interquartile range. Interestingly they are all in the same direction such that the outliers are larger than the reported means.

```r
## Now identify the outliers
out_ind1 <- which(in.data$Magnesium %in% boxplot.stats(in.data$Magnesium)$out)
out_ind2 <- which(in.data$Color_intensity %in% boxplot.stats(in.data$Color_intensity)$out)
out_ind3 <- which(in.data$Malic_acid %in% boxplot.stats(in.data$Malic_acid)$out)
out_ind <- union(out_ind1, out_ind2)
out_ind <- union(out_ind, out_ind3)
## Remove the outliers from the data
long_dt <- in.data[-out_ind,]
## Now print the data frame
kable(
  long_dt,
  format    = "latex",
  longtable = T,
  booktabs  = T,
  caption   = "Longtable"
) %>%
  add_header_above(c(" ", "Group 1" = 5, "Group 2" = 6)) %>%
  kable_styling(latex_options = c("repeat_header"),
                repeat_header_continued = "\\textit{(Continued on Next Page...)}")
```

Table 1: Longtabl

	Group 1					Grou			
	Cultivar	Alcohol	Malic_acid	Ash	Alcalinity_of_ash	Magnesium	Total_phenols	Flavanoids	Nonflava
1	1	14.23	1.71	2.43	15.6	127	2.80	3.06	
2	1	13.20	1.78	2.14	11.2	100	2.65	2.76	
3	1	13.16	2.36	2.67	18.6	101	2.80	3.24	
4	1	14.37	1.95	2.50	16.8	113	3.85	3.49	
5	1	13.24	2.59	2.87	21.0	118	2.80	2.69	
6	1	14.20	1.76	2.45	15.2	112	3.27	3.39	
7	1	14.39	1.87	2.45	14.6	96	2.50	2.52	
8	1	14.06	2.15	2.61	17.6	121	2.60	2.51	
9	1	14.83	1.64	2.17	14.0	97	2.80	2.98	
10	1	13.86	1.35	2.27	16.0	98	2.98	3.15	
11	1	14.10	2.16	2.30	18.0	105	2.95	3.32	
12	1	14.12	1.48	2.32	16.8	95	2.20	2.43	
13	1	13.75	1.73	2.41	16.0	89	2.60	2.76	
14	1	14.75	1.73	2.39	11.4	91	3.10	3.69	
15	1	14.38	1.87	2.38	12.0	102	3.30	3.64	
16	1	13.63	1.81	2.70	17.2	112	2.85	2.91	
17	1	14.30	1.92	2.72	20.0	120	2.80	3.14	
18	1	13.83	1.57	2.62	20.0	115	2.95	3.40	
19	1	14.19	1.59	2.48	16.5	108	3.30	3.93	
20	1	13.64	3.10	2.56	15.2	116	2.70	3.03	
21	1	14.06	1.63	2.28	16.0	126	3.00	3.17	
22	1	12.93	3.80	2.65	18.6	102	2.41	2.41	

Table 1: Longtable *(cor*

	Group 1					Grou			
	Cultivar	Alcohol	Malic_acid	Ash	Alcalinity_of_ash	Magnesium	Total_phenols	Flavanoids	Nonflava
23	1	13.71	1.86	2.36	16.6	101	2.61	2.88	
24	1	12.85	1.60	2.52	17.8	95	2.48	2.37	
25	1	13.50	1.81	2.61	20.0	96	2.53	2.61	
26	1	13.05	2.05	3.22	25.0	124	2.63	2.68	
27	1	13.39	1.77	2.62	16.1	93	2.85	2.94	
28	1	13.30	1.72	2.14	17.0	94	2.40	2.19	
29	1	13.87	1.90	2.80	19.4	107	2.95	2.97	
30	1	14.02	1.68	2.21	16.0	96	2.65	2.33	
31	1	13.73	1.50	2.70	22.5	101	3.00	3.25	
32	1	13.58	1.66	2.36	19.1	106	2.86	3.19	
33	1	13.68	1.83	2.36	17.2	104	2.42	2.69	
34	1	13.76	1.53	2.70	19.5	132	2.95	2.74	
35	1	13.51	1.80	2.65	19.0	110	2.35	2.53	
36	1	13.48	1.81	2.41	20.5	100	2.70	2.98	
37	1	13.28	1.64	2.84	15.5	110	2.60	2.68	
38	1	13.05	1.65	2.55	18.0	98	2.45	2.43	
39	1	13.07	1.50	2.10	15.5	98	2.40	2.64	
40	1	14.22	3.99	2.51	13.2	128	3.00	3.04	
41	1	13.56	1.71	2.31	16.2	117	3.15	3.29	
42	1	13.41	3.84	2.12	18.8	90	2.45	2.68	
43	1	13.88	1.89	2.59	15.0	101	3.25	3.56	
44	1	13.24	3.98	2.29	17.5	103	2.64	2.63	
45	1	13.05	1.77	2.10	17.0	107	3.00	3.00	
46	1	14.21	4.04	2.44	18.9	111	2.85	2.65	
47	1	14.38	3.59	2.28	16.0	102	3.25	3.17	
48	1	13.90	1.68	2.12	16.0	101	3.10	3.39	
49	1	14.10	2.02	2.40	18.8	103	2.75	2.92	
50	1	13.94	1.73	2.27	17.4	108	2.88	3.54	
51	1	13.05	1.73	2.04	12.4	92	2.72	3.27	
52	1	13.83	1.65	2.60	17.2	94	2.45	2.99	
53	1	13.82	1.75	2.42	14.0	111	3.88	3.74	
54	1	13.77	1.90	2.68	17.1	115	3.00	2.79	
55	1	13.74	1.67	2.25	16.4	118	2.60	2.90	
56	1	13.56	1.73	2.46	20.5	116	2.96	2.78	
57	1	14.22	1.70	2.30	16.3	118	3.20	3.00	
58	1	13.29	1.97	2.68	16.8	102	3.00	3.23	
59	1	13.72	1.43	2.50	16.7	108	3.40	3.67	
60	2	12.37	0.94	1.36	10.6	88	1.98	0.57	
61	2	12.33	1.10	2.28	16.0	101	2.05	1.09	
62	2	12.64	1.36	2.02	16.8	100	2.02	1.41	
63	2	13.67	1.25	1.92	18.0	94	2.10	1.79	
64	2	12.37	1.13	2.16	19.0	87	3.50	3.10	
65	2	12.17	1.45	2.53	19.0	104	1.89	1.75	
66	2	12.37	1.21	2.56	18.1	98	2.42	2.65	

Table 1: Longtable *(cor*

	Group 1					Grou			
	Cultivar	Alcohol	Malic_acid	Ash	Alcalinity_of_ash	Magnesium	Total_phenols	Flavanoids	Nonflava
67	2	13.11	1.01	1.70	15.0	78	2.98	3.18	
68	2	12.37	1.17	1.92	19.6	78	2.11	2.00	
69	2	13.34	0.94	2.36	17.0	110	2.53	1.30	
71	2	12.29	1.61	2.21	20.4	103	1.10	1.02	
72	2	13.86	1.51	2.67	25.0	86	2.95	2.86	
73	2	13.49	1.66	2.24	24.0	87	1.88	1.84	
75	2	11.96	1.09	2.30	21.0	101	3.38	2.14	
76	2	11.66	1.88	1.92	16.0	97	1.61	1.57	
77	2	13.03	0.90	1.71	16.0	86	1.95	2.03	
78	2	11.84	2.89	2.23	18.0	112	1.72	1.32	
80	2	12.70	3.87	2.40	23.0	101	2.83	2.55	
81	2	12.00	0.92	2.00	19.0	86	2.42	2.26	
82	2	12.72	1.81	2.20	18.8	86	2.20	2.53	
83	2	12.08	1.13	2.51	24.0	78	2.00	1.58	
84	2	13.05	3.86	2.32	22.5	85	1.65	1.59	
85	2	11.84	0.89	2.58	18.0	94	2.20	2.21	
86	2	12.67	0.98	2.24	18.0	99	2.20	1.94	
87	2	12.16	1.61	2.31	22.8	90	1.78	1.69	
88	2	11.65	1.67	2.62	26.0	88	1.92	1.61	
89	2	11.64	2.06	2.46	21.6	84	1.95	1.69	
90	2	12.08	1.33	2.30	23.6	70	2.20	1.59	
91	2	12.08	1.83	2.32	18.5	81	1.60	1.50	
92	2	12.00	1.51	2.42	22.0	86	1.45	1.25	
93	2	12.69	1.53	2.26	20.7	80	1.38	1.46	
94	2	12.29	2.83	2.22	18.0	88	2.45	2.25	
95	2	11.62	1.99	2.28	18.0	98	3.02	2.26	
97	2	11.81	2.12	2.74	21.5	134	1.60	0.99	
98	2	12.29	1.41	1.98	16.0	85	2.55	2.50	
99	2	12.37	1.07	2.10	18.5	88	3.52	3.75	
100	2	12.29	3.17	2.21	18.0	88	2.85	2.99	
101	2	12.08	2.08	1.70	17.5	97	2.23	2.17	
102	2	12.60	1.34	1.90	18.5	88	1.45	1.36	
103	2	12.34	2.45	2.46	21.0	98	2.56	2.11	
104	2	11.82	1.72	1.88	19.5	86	2.50	1.64	
105	2	12.51	1.73	1.98	20.5	85	2.20	1.92	
106	2	12.42	2.55	2.27	22.0	90	1.68	1.84	
107	2	12.25	1.73	2.12	19.0	80	1.65	2.03	
108	2	12.72	1.75	2.28	22.5	84	1.38	1.76	
109	2	12.22	1.29	1.94	19.0	92	2.36	2.04	
110	2	11.61	1.35	2.70	20.0	94	2.74	2.92	
111	2	11.46	3.74	1.82	19.5	107	3.18	2.58	
112	2	12.52	2.43	2.17	21.0	88	2.55	2.27	
113	2	11.76	2.68	2.92	20.0	103	1.75	2.03	
114	2	11.41	0.74	2.50	21.0	88	2.48	2.01	

Table 1: Longtable *(cor*

	Group 1					Grou			
	Cultivar	Alcohol	Malic_acid	Ash	Alcalinity_of_ash	Magnesium	Total_phenols	Flavanoids	Nonflava
115	2	12.08	1.39	2.50	22.5	84	2.56	2.29	
116	2	11.03	1.51	2.20	21.5	85	2.46	2.17	
117	2	11.82	1.47	1.99	20.8	86	1.98	1.60	
118	2	12.42	1.61	2.19	22.5	108	2.00	2.09	
119	2	12.77	3.43	1.98	16.0	80	1.63	1.25	
120	2	12.00	3.43	2.00	19.0	87	2.00	1.64	
121	2	11.45	2.40	2.42	20.0	96	2.90	2.79	
122	2	11.56	2.05	3.23	28.5	119	3.18	5.08	
123	2	12.42	4.43	2.73	26.5	102	2.20	2.13	
125	2	11.87	4.31	2.39	21.0	82	2.86	3.03	
126	2	12.07	2.16	2.17	21.0	85	2.60	2.65	
127	2	12.43	1.53	2.29	21.5	86	2.74	3.15	
128	2	11.79	2.13	2.78	28.5	92	2.13	2.24	
129	2	12.37	1.63	2.30	24.5	88	2.22	2.45	
130	2	12.04	4.30	2.38	22.0	80	2.10	1.75	
131	3	12.86	1.35	2.32	18.0	122	1.51	1.25	
132	3	12.88	2.99	2.40	20.0	104	1.30	1.22	
133	3	12.81	2.31	2.40	24.0	98	1.15	1.09	
134	3	12.70	3.55	2.36	21.5	106	1.70	1.20	
135	3	12.51	1.24	2.25	17.5	85	2.00	0.58	
136	3	12.60	2.46	2.20	18.5	94	1.62	0.66	
137	3	12.25	4.72	2.54	21.0	89	1.38	0.47	
139	3	13.49	3.59	2.19	19.5	88	1.62	0.48	
140	3	12.84	2.96	2.61	24.0	101	2.32	0.60	
141	3	12.93	2.81	2.70	21.0	96	1.54	0.50	
142	3	13.36	2.56	2.35	20.0	89	1.40	0.50	
143	3	13.52	3.17	2.72	23.5	97	1.55	0.52	
144	3	13.62	4.95	2.35	20.0	92	2.00	0.80	
145	3	12.25	3.88	2.20	18.5	112	1.38	0.78	
146	3	13.16	3.57	2.15	21.0	102	1.50	0.55	
147	3	13.88	5.04	2.23	20.0	80	0.98	0.34	
148	3	12.87	4.61	2.48	21.5	86	1.70	0.65	
149	3	13.32	3.24	2.38	21.5	92	1.93	0.76	
150	3	13.08	3.90	2.36	21.5	113	1.41	1.39	
151	3	13.50	3.12	2.62	24.0	123	1.40	1.57	
153	3	13.11	1.90	2.75	25.5	116	2.20	1.28	
154	3	13.23	3.30	2.28	18.5	98	1.80	0.83	
155	3	12.58	1.29	2.10	20.0	103	1.48	0.58	
156	3	13.17	5.19	2.32	22.0	93	1.74	0.63	
157	3	13.84	4.12	2.38	19.5	89	1.80	0.83	
158	3	12.45	3.03	2.64	27.0	97	1.90	0.58	
161	3	12.36	3.83	2.38	21.0	88	2.30	0.92	
162	3	13.69	3.26	2.54	20.0	107	1.83	0.56	
163	3	12.85	3.27	2.58	22.0	106	1.65	0.60	

Table 1: Longtable *(cor*

	Group 1					Grou			
	Cultivar	Alcohol	Malic_acid	Ash	Alcalinity_of_ash	Magnesium	Total_phenols	Flavanoids	Nonflava
164	3	12.96	3.45	2.35	18.5	106	1.39	0.70	
165	3	13.78	2.76	2.30	22.0	90	1.35	0.68	
166	3	13.73	4.36	2.26	22.5	88	1.28	0.47	
167	3	13.45	3.70	2.60	23.0	111	1.70	0.92	
168	3	12.82	3.37	2.30	19.5	88	1.48	0.66	
169	3	13.58	2.58	2.69	24.5	105	1.55	0.84	
170	3	13.40	4.60	2.86	25.0	112	1.98	0.96	
171	3	12.20	3.03	2.32	19.0	96	1.25	0.49	
172	3	12.77	2.39	2.28	19.5	86	1.39	0.51	
173	3	14.16	2.51	2.48	20.0	91	1.68	0.70	
175	3	13.40	3.91	2.48	23.0	102	1.80	0.75	
176	3	13.27	4.28	2.26	20.0	120	1.59	0.69	
177	3	13.17	2.59	2.37	20.0	120	1.65	0.68	
178	3	14.13	4.10	2.74	24.5	96	2.05	0.76	

c)

```r
# Now make a plot of the Magnesium; Color Intensity; and Malic Acid
out.plot.standard <- long_dt[,c("Magnesium", "Color_intensity", "Malic_acid")] %>%
  mutate(across(where(is.numeric), scale)) %>%
  reshape2::melt(.) %>%
  ggplot(., aes(x=variable, y=value)) +
  geom_boxplot() +
  theme_bw() +
  ggtitle("z-score values boxplot")
```

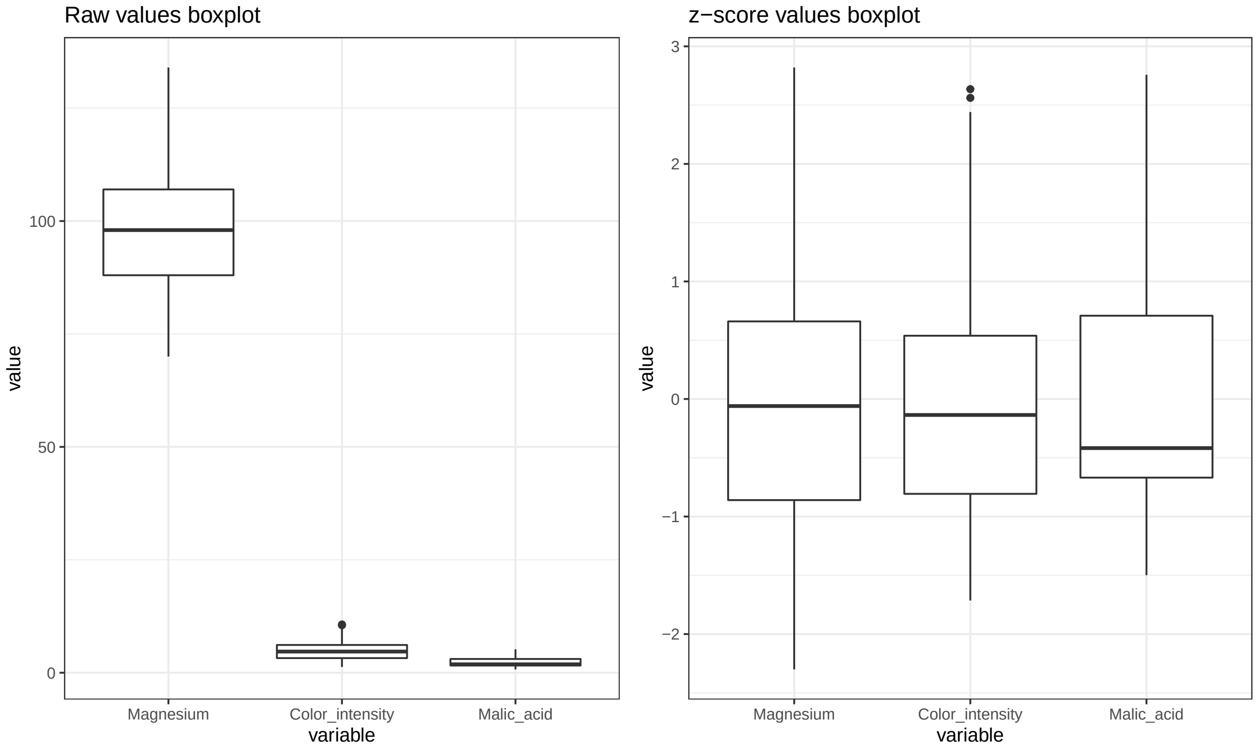
```
No id variables; using all as measure variables
```

```
Warning: attributes are not identical across measure variables; they will be
dropped
```

```r
out.plot.raw <- long_dt[,c("Magnesium", "Color_intensity", "Malic_acid")] %>%
  #mutate(across(where(is.numeric), scale)) %>%
  reshape2::melt(.) %>%
  ggplot(., aes(x=variable, y=value)) +
  geom_boxplot() +
  theme_bw() +
  ggtitle("Raw values boxplot")
```

```
No id variables; using all as measure variables
```

```r
multiplot(out.plot.raw, out.plot.standard, cols = 2)
```



Seen above it appears these three variables now do not posses outliers and follow a relativley normal distribution.