ANOVA Testing in R studios

Hypothesis Testing for 8 interaction techniques:

```r
#Inputing Data: Analysis Excel sheet has "Time" data of 8 interaction techniques
library(openxlsx)
library(stats)
library(gridExtra)
library(grid)
data <- read.xlsx("Analysis.xlsx",colNames = FALSE, sheet="Time")
#Transpose
time <- c(data[,1], data[,2], data[,3], data[,4], data[,5],
                 data[,6], data[,7], data[,8])
techniques <- c(rep('technique1', 8),rep('technique2', 8),rep('technique3', 8),
                rep('technique4', 8),rep('technique5', 8),rep('technique6', 8),
                rep('technique7', 8),rep('technique8', 8))
combine <- cbind((time), techniques)
```

Computing Mean and Standard Deviation of 8 techniques

```r
mean1<- mean(data$X1)
sd1 = sqrt(var(data$X1))

mean2<- mean(data$X2)
sd2 = sqrt(var(data$X2))

mean3<- mean(data$X3)
sd3 = sqrt(var(data$X3))

mean4<- mean(data$X4)
sd4 = sqrt(var(data$X4))

mean5<- mean(data$X5)
sd5 = sqrt(var(data$X5))

mean6<- mean(data$X6)
sd6 = sqrt(var(data$X6))

mean7<- mean(data$X7)
sd7 = sqrt(var(data$X7))

mean8<- mean(data$X8)
sd8 = sqrt(var(data$X8))
```

```r
# Print in table
r1 <- c("Technique id", "Mean", "Standard Deviation")
r2 <- c("1", round(mean1, 2), round(sd1, 2))
r3 <- c("2", round(mean2, 2), round(sd2, 2))
r4 <- c("3", round(mean3, 2), round(sd3, 2))
r5 <- c("4", round(mean4, 2), round(sd4, 2))
r6 <- c("5", round(mean5, 2), round(sd5, 2))
r7 <- c("6", round(mean6, 2), round(sd6, 2))
r8 <- c("7", round(mean7, 2), round(sd7, 2))
r9 <- c("8", round(mean8, 2), round(sd8, 2))
tab <- rbind(r1, r2, r3, r4, r5, r6, r7,r8,r9)
grid.table(tab, rows = NULL)
```

Technique id	Mean	Standard Deviation
1	6481.38	3005.29
2	5818.75	3897.97
3	4716.25	2270.69
4	4096	2614.97
5	8671.75	1705.49
6	8110.88	3087
7	8855.62	2837.9
8	6261.62	2617.7

Anova Tests : Mean Time Completion

An ANOVA test is a type of statistical test used to determine if there is a statistically significant difference between two or more categorical groups by testing for differences of means using variance.

Study Populations: We have 8 participants in total

Population 1:

Population 2:

Research hypotheses: Not all the means of the techniques are equal.

Null hypotheses: All the mean of the techniques are equal

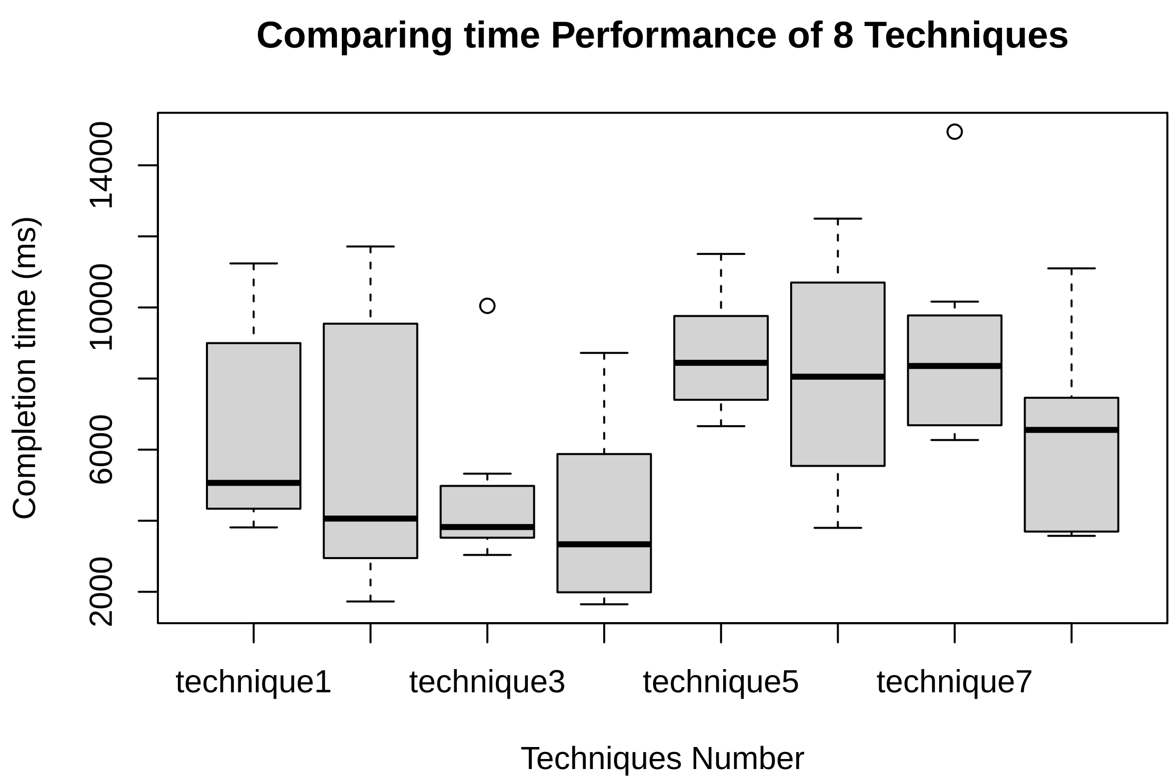
```r
results <- aov(time ~ techniques)
anova(results)
```

```
## Analysis of Variance Table
##
## Response: time
##            Df    Sum Sq  Mean Sq F value  Pr(>F)
## techniques  7 177716443 25388063  3.1953 0.00644 **
## Residuals  56 444950039  7945536
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The decision is to reject the null hypothesis, as the p-value is < 0.05. There is sufficient evidence to see that the mean values for all techniques are not all equal. At least two of these techniques has mean values that were different from each other.

Creating side by side box plots

```r
boxplot(time~techniques,main = "Comparing time Performance of 8 Techniques",
        xlab = "Techniques Number", ylab = "Completion time (ms)")
```



The boxplots show that the differences in performance in terms of time for techniques 4,5 and 4, 7 due to how little of the boxplots "overlap". However, technique 1,2,3,4 and 8 overlap significantly, so there will likely be some similarities. Additionally, techniques 5,6,7 also overlap quite a bit, indicating that we may find some similarities in those techniques as well. This is supported by the mean of techniques 5 and 7 being similar to each other, as well as the mean of the techniques 1 and 8 having similar means. It is also evident that the techniques 4, 5 and 4, 7 have more of a difference in their means.

Tukey HSD (Honest Significant Difference) post hoc comparision

A pairwise comparison technique that uses the Studentized range distribution to construct simultaneous confidence intervals for differences of all pairs of means. Studentization means dividing a mean value by its standard error. We are computing the Tukey HSD with confidence level of 0.95.

```
TukeyHSD(results, conf.level=0.95)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = time ~ techniques)
##
## $techniques
##                             diff        lwr      upr     p adj
## technique2-technique1  -662.625 -5099.7876 3774.538 0.9997460
## technique3-technique1 -1765.125 -6202.2876 2672.038 0.9120290
## technique4-technique1 -2385.375 -6822.5376 2051.788 0.6919066
## technique5-technique1  2190.375 -2246.7876 6627.538 0.7746530
## technique6-technique1  1629.500 -2807.6626 6066.663 0.9407470
## technique7-technique1  2374.250 -2062.9126 6811.413 0.6968555
## technique8-technique1  -219.750 -4656.9126 4217.413 0.9999999
## technique3-technique2 -1102.500 -5539.6626 3334.663 0.9934061
## technique4-technique2 -1722.750 -6159.9126 2714.413 0.9217980
## technique5-technique2  2853.000 -1584.1626 7290.163 0.4754423
## technique6-technique2  2292.125 -2145.0376 6729.288 0.7326169
## technique7-technique2  3036.875 -1400.2876 7474.038 0.3941837
## technique8-technique2   442.875 -3994.2876 4880.038 0.9999833
## technique4-technique3  -620.250 -5057.4126 3816.913 0.9998365
## technique5-technique3  3955.500  -481.6626 8392.663 0.1139950
## technique6-technique3  3394.625 -1042.5376 7831.788 0.2575240
## technique7-technique3  4139.375  -297.7876 8576.538 0.0842657
## technique8-technique3  1545.375 -2891.7876 5982.538 0.9549444
## technique5-technique4  4575.750   138.5874 9012.913 0.0387199
## technique6-technique4  4014.875  -422.2876 8452.038 0.1035796
## technique7-technique4  4759.625   322.4624 9196.788 0.0272632
## technique8-technique4  2165.625 -2271.5376 6602.788 0.7844333
## technique6-technique5  -560.875 -4998.0376 3876.288 0.9999168
## technique7-technique5   183.875 -4253.2876 4621.038 1.0000000
## technique8-technique5 -2410.125 -6847.2876 2027.038 0.6808185
## technique7-technique6   744.750 -3692.4126 5181.913 0.9994506
## technique8-technique6 -1849.250 -6286.4126 2587.913 0.8904553
## technique8-technique7 -2594.000 -7031.1626 1843.163 0.5960337
```

As we can see from the table above, technique 5 technique 4 has $p(= 0.0387199) < 0.05$ and technique 7 and technique 4 has $p(= 0.0272632) < 0.05$. SO we can conclude that technique 4 has different mean than technique 5 and 7. Therefore, technique 4 is significantly faster than technique 5 and 7.