The University of Sydney
STAT2012 Statistical Tests

Semester 2	Computer Practice Week 8	2015

Useful R commands

- Two-way ANOVA test: To test

$$H_0: \beta_1 = \cdots = \beta_c \quad \text{vs} \quad H_1: \text{ at least one } \beta_j \text{ does not equal; } \quad \text{and/or}$$
$$H_0: \alpha_1 = \cdots = \alpha_r \quad \text{vs} \quad H_1: \text{ at least one } \alpha_i \text{ does not equal;}$$

the R codes are

```
xv=as.matrix(x)
xv=as.vector(xv)
factor.tr=factor(rep(letters[1:c],c(r,r,...,r)))
factor.tr
factor.bl=factor(rep(letters[1:r],c))
factor.bl
aov.x=aov(xv~factor.tr+factor.bl)
summary(aov.x)
```

where `x` is a `r` × `c` matrix with `r` rows (blocks) and `c` columns (treatments).

Important points

- You will *compare the performance* of the one-way ANOVA test and Kruskal-Wallis test to test the equality of means across $g > 2$ populations when there is an *outlier*.
- You will perform the two-way ANOVA test to compare the means of $c > 2$ treatment groups in a two-way data with blocks.
- You will drop the block effect and compare the result of one-way ANOVA test with that of two-way ANOVA test.

Practice Problems

1. The table below gives the energy use of five (`c=5`) gas `range` for seven (`r=7`) menu days.

```
   R1   R2   R3   R4   R5

1 8.25 8.26 6.55 8.21 6.69
2 5.12 4.81 3.87 4.81 3.99
3 5.32 4.37 3.76 4.67 4.37
4 8.00 6.50 5.38 6.51 5.60
5 6.97 6.26 5.03 6.40 5.60
6 7.65 5.84 5.23 6.24 5.73
7 7.86 7.31 5.87 6.64 6.03
```

Open the data set `range`.

```
range=read.csv("http://www.maths.usyd.edu.au/u/UG/IM/STAT2012/r/range.csv")
attach(range)
range
```

Conduct the following tests for the equality of means across gas ranges.

(a) State the null and alternative hypotheses for the tests.

(b) Perform the *one-way ANOVA* test on the `range` and draw your conclusion based on the p-value.

Hint: Since this data have a *matrix* format, you need to create vectors of outcomes `rangev` and factor labels `factor` as last week.

(c) Create a new data set `range1` which is the same as `range` except the third R4 observation is accidentally entered as 46.7 rather than 4.67. Perform the one-way ANOVA test on the `range1` and draw your conclusion based on the p-value. Compare the SST and SSR with an outlier to those in (b) without an outlier.

```
range1=range
range1[3,4]=46.7
range1
...
```

(d) Draw the boxplots and the qq-plots for the combined residuals of the data `range` and `range1` respectively. Comment on whether or not each of the data appears to satisfy the *equality of variance* and *normality* assumptions for the one-way ANOVA test.

(e) Perform the *Kruskal-Wallis* test on the data `range1`. Compare the result with that in (c) and comment on the effect of an outlier on the one-way ANOVA and Kruskal-Wallis tests.

2. The table below gives the estimated repair costs for cars 1 to 6 (`r=6`) from three (`c=3`) appraisers of an automobile insurance company.

	Appraiser.1	Appraiser.2	Appraiser.3
Car 1	650	600	750
Car 2	930	910	1010
Car 3	440	450	500
Car 4	750	710	810
Car 5	1190	1050	1250
Car 6	1560	1270	1450

Open the data set `auto`.

```
auto=read.csv("http://www.maths.usyd.edu.au/u/UG/IM/STAT2012/r/auto.csv")
attach(auto)
auto
```

Test if the estimated repair costs differ across appraisers using the *two-way ANOVA* test.

(a) State the null and alternative hypotheses.

(b) Perform the two-way ANOVA test and report the test statistic and p-value. Draw your conclusion about H_0 based on the p-value. Does the estimated repair cost differ across appraisers?

Hint: Since this data have a *matrix* format, you need to create vectors of outcomes `autov` and factor labels `factor.tr` and `factor.bl`.

(c) Draw the *residual* plot and normal qq plots for the combined residuals. Comment the equality-of-variance, independence and normality assumptions for residuals.

(d) Perform the one-way ANOVA test using only `factor.tr` and report the test statistic and p-value. Draw your conclusion about H_0 based on the p-value. Does the estimated repair cost differ across appraisers?

Report the SSR for both one-way and two-way ANOVA tests and explain why SSR is much inflated in one-way ANOVA test (Hint: consider SSB in two-way ANOVA test). Based on the two SSR, explain why the results from one-way and two-way ANOVA tests do not agree.

(e) Draw the boxplot for each *appraiser*. This serves as a synonym to the one-way ANOVA test. Compare the variability across appraisers' medians with the variability within each appraiser. Hence comment on the inclusion of *blocks* using car size in the two-way ANOVA test?