Assignment 3, ST2304

Problem 1

The seeds of the Maple tree disperse using a helicopter-like flight mechanism. In this exercise we have carried out some research to investigate how properties of paper model "helicopters" influence their flying ability, using a three-way analysis of variance with the following three factors:

- Helicopter size. We have two levels for this factor; small and large.
- Wing shape. We have three levels for this factor; control, down and up. Helicopters in the control group should not have their wings folded; helicopters in the "down" group should have their wings folded downwards and helicopters in the "up" group should have their wings folded upward.
- Finally, to some helicopters we attached some extra weight by means of a small paper clip. This factor thus has two levels representing whether a clip is present or not.

To obtain a so called balanced design we measured flying ability (the response variable) the same number of times (twice) for each combination of the three factors. A total of $(2\times 3\times 2)\times 2 = 24$ experiments have thus been done. The results can be read into R using the command

```
heli <-
read.csv("http://www.math.ntnu.no/~diserud/ST2304/helicopterdata.csv")
attach(heli)
```

This (first saving in csv-format) is the recommended way of getting data from Microsoft Excel into R. Make sure that the variables are properly encoded as categorical variables, so called factors (`summary(heli)` may tell you about this). Then fit a linear model using the command

```
helimod <- lm(flighttime ~ size + wing + clip)
```

1. Interpret the output you see when you run the command

   ```
   anova(helimod)
   ```

   Based on the sum of squares associated with each factor, which of the factors explains the largest proportion of the total variance?

2. Which factors have a significant effect on flight time?
3. Are any of the factors non-significant at a level of significance of $\alpha = 0.05$? If so, you may want to remove non-significant factors from the model and fit a reduced model.
4. If you remove one of the factors, how does this change the sum of squares associated with the other factors? Does it change the statistical significance of the other factors?
5. Estimates of the different parameters can be obtained using

   ```
   summary(helimod)
   ```

   What is the estimated effect (in seconds) of small helicopter size on flight time relative to that of large size?

6. What is the estimated effect (in seconds) of wings of type down and up relative to the control wing type?
7. What is the estimated effect (in seconds) of attaching a paper clip on flight time?
8. Inspect to the output from `summary( )` to determine if any of the above effects are statistically significant.
9. Again, provided that the design is balanced, parameter estimates (other than the estimate of the intercept) should not change when one of the factors are removed. Verify that this is the case.
10. We have made the assumption that the different factors affect flight time additively. We have also assumed that the residuals in the model are normally distributed. Do you think that these assumptions are reasonable?

Figure 1: A “small” helicopter without a paper clip and with wings folded “down”.