

Assignment 3, ST2304

Problem 1 The seeds of the Maple tree disperse using a helicopter like flight mechanism. In this exercise we will carry 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 will use two levels for this factor; small (see page 4) and large (see page 5)
- Wing shape. We will use 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 will attach some extra weight by means of a small paper clip. This factor thus have two levels representing whether a clip is present or not.

To obtain a so called balanced design we will measure 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 will thus have to be done. To record the results we will use this Google docs spreadsheet (Google docs makes collaborative, simultaneous editing of the same file possible).

It will be a good idea to collaborate in small groups when doing these experiments. Each group may then take responsibility for a subset of the necessary experiments. To avoid unnecessary replications you may want to indicate that your group is taking responsibility for a certain subset by filling in a nickname for your group in the column `nick` before proceeding.

The helicopters should be made from the designs on page 4 and 5. Solid lines indicate where you should cut the paper with a scissor. Dashed and dotted lines indicate that you should fold the paper towards or away from you, respectively. The end result should look something like what you see in Figure 1.

To measure flying ability (the response variable) the helicopters should be dropped from a suitable place at the first floor in Realfagsbygget (D1) from which the helicopter can descend freely down into DU3. Using a stopwatch (most of you probably have one on your mobile phone), record the time (in seconds) the helicopter uses before reaching the floor in DU3. Fill in the results into column `flighttime` into the above Google docs spreadsheet.

Statistical analysis

When all the experiments are complete, download the spreadsheet to your local home directory by choosing “File/Download as/CSV” from the Google docs menu. Then read the data into R using the command

```
heli <- read.csv("z:/folder/helicopterdata.csv")
attach(heli)
```

if this is where you saved the file. Note that you need forward and not backward slashes in the file name. This (first saving in csv-format) is also 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 flighttime?
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)
```

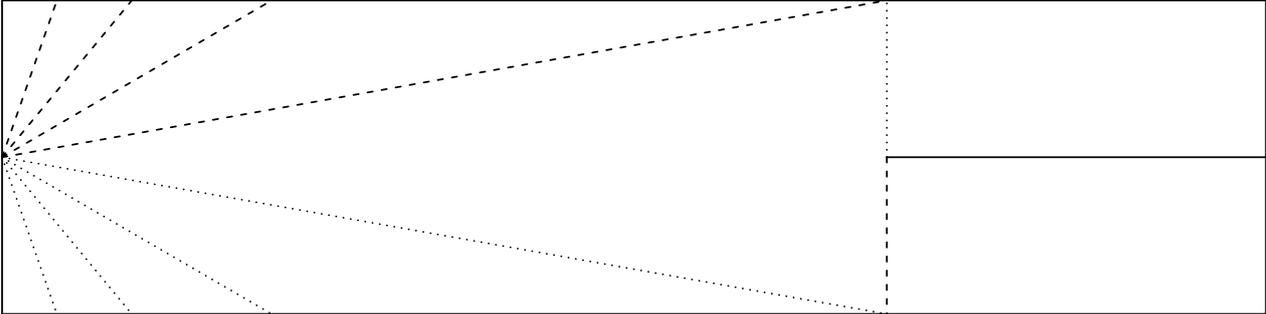
What is the estimated effect (in seconds) of small helicoptersize on flighttime relative to that of large size.

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 flighttime?
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 flighttime additatively. We have also assumed that the residuals in the model are normally distributed. Do you think these assumptions are reasonable?

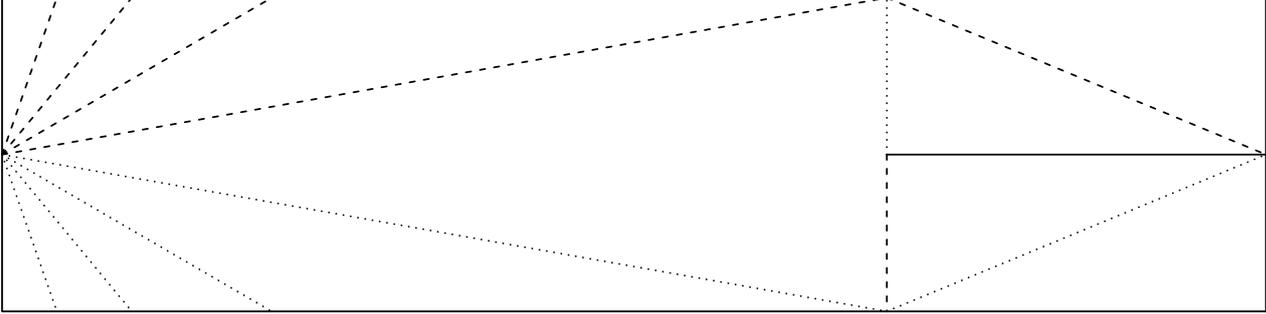


Figure 1: A “small” helicopter without a paper clip and with wings folded “down”.

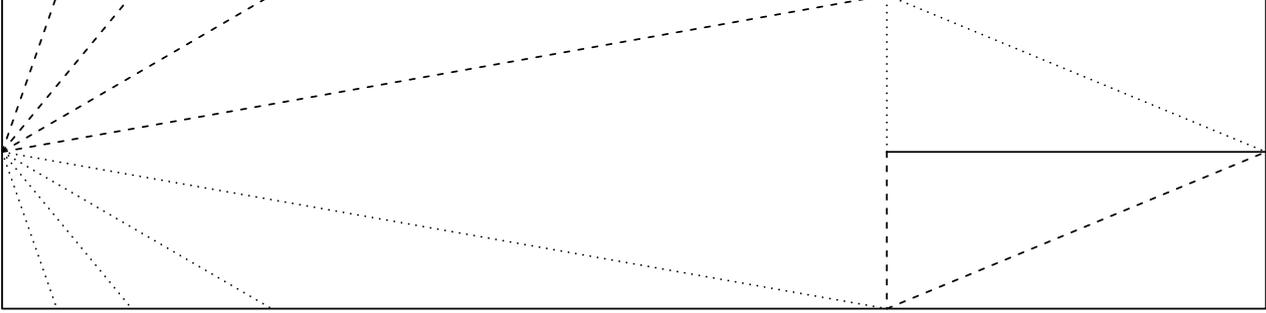
size=small
wing=control



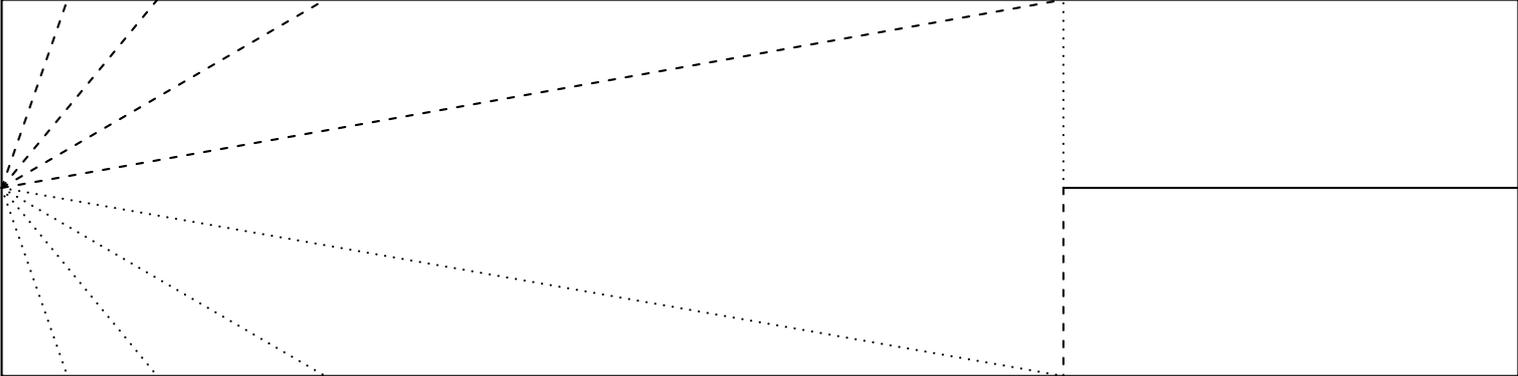
wing=up



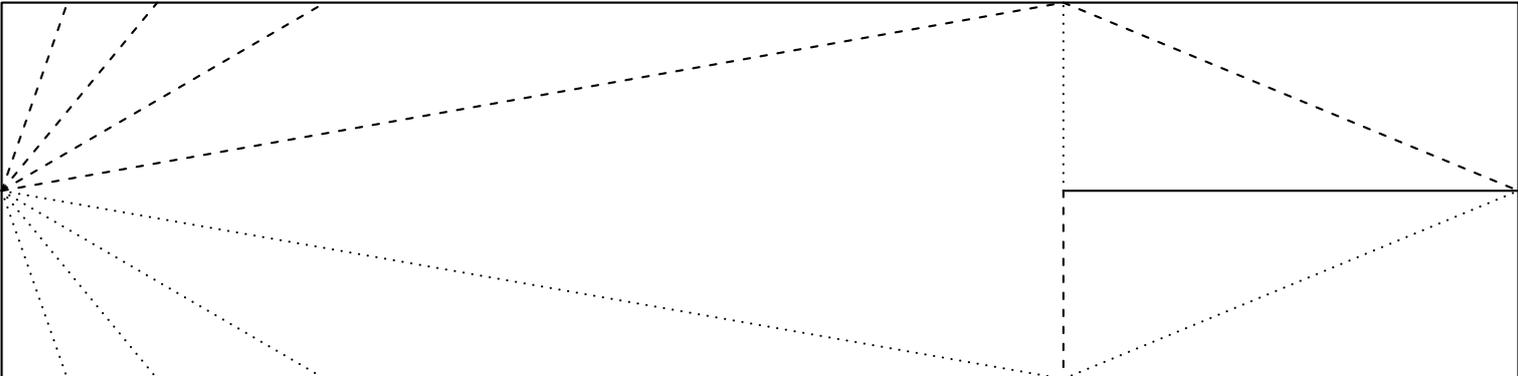
wing=down



size=large
wing=control



wing=up



wing=down

