Paper helicopter flight time optimization

Introduction

The goal of this **final project** is to give you experience in all phases of a statistical study using response surface analysis: planning, data collection, analysis, and conclusions. In this activity your group is asked to construct a helicopter that when dropped from a height and allowed to fall freely, will stay in the air as long as possible. One possible design for the helicopter is given in Figure 1 on page 4. The activity will consist of two parts:

Part I. Design, conduct, and analyze one or more screening experiments to identify the vital few factors determining flight time.

Part II. Design, conduct, and analyze a sequence of experiments to map the response surface and identify factor settings to optimize flight time.

Experimental Procedure

Part I: Screening Experiments

1. You must initially identify a set of at least seven relevant factors such as

   - rotor length
   - rotor width
   - body length
   - fold length
   - fold width
   - absence/presence of paper clip (or weight of paper clip),

   or any other factors you think might affect the dropping times. You are free to make modifications to the design, but you need to incorporate them into the experimental design scheme.

   You might begin by constructing the stock helicopter illustrated in Figure 1 and conducting a few test runs. You can then combine the knowledge gained from piloting this helicopter with the knowledge you have obtained about planning experiments to obtain a list of factors to be considered and levels for those factors. Note that these factors need not be limited just to the obvious ones listed previously. Incorporate what you have learned about the organization and the quality control of experiments into the conduct of your experiments as well. Consider some brain-storming tools in the "Pre-design experiment guide sheet" at the bottom of the course webpage.

   To put this in context, in an industrial setting, you might be at the initial stage of investigation, in which your eventual goal is to optimize the output or reduce the variability or in some other way improve the performance of a process. At this stage, your goal is to identify the influential factors governing the response you are trying to improve. In this part, you will use the response-surface techniques of Chapters 2–4 to do so.

   In Part II of this activity, you will be asked to use experimental design techniques to find the helicopter design that will stay aloft the longest, so you might keep this in mind you conduct the experiments for Part I.

2. Set up an experimental protocol. This describes exactly how your experiment is to be run, including what factors at what levels and in what order.

   Also, consider blocking as a device for reducing variation when all the runs of an experiment can't be performed under homogeneous conditions; use the motto, "block what you can, randomize the rest" for helicopter creation, dropping, and anything else. For example, if some helicopters are dropped by one teammate and timed by another, and other helicopters are dropped by another teammate, then those could be considered separate blocks.

3. Collect the data and analyze the results.

4. The results from your first experiment will likely lead to further experiments as you seek to resolve confounding and identify the vital few significant factors in keeping the helicopter aloft.

Part II: Optimizing

Once you have obtained the vital few significant factors from Part I, it is time to begin optimizing your design. In this part, you will use the response-surface techniques of Chapters 5–7 to do so. Exactly how you proceed will depend on the results from Part I (so it might be a good idea to have a talk with your instructor).

Reporting the Results

You are to write a single report in the project report format (see end of document). In addition to the general instructions for a project report, you should also include the following:

For Part I

1. A description of the **process** of experimentation you used. Include information on the tools and techniques you used to plan and conduct the experiments. Tell what steps you took to maintain the quality of experimentation.

2. A description of your experiments, including the configurations run, the factors you identified, the levels of the factors used in the experiments, and the responses observed. In other words, a complete description of your experiments and the data from those experiments. Also include the reasons for your choices.

3. The results of confirmatory experiments.

4. Your conclusions. These should include the factors that were important and unimportant in determining the response and whether there was significant curvature or interaction.

5. A critique of your experiments. What went right? What went wrong? How could the experiments be improved? How confident are you in your data?

For Part II

1. A description of the **process** of experimentation you used. Include information on the tools and techniques you used to plan and conduct the experiments. Tell what steps you took to maintain the quality of experimentation.

2. A description of your experiments, including the configurations run, the factors you identified, the levels of the factors used in the experiments, and the responses observed. In other words, a complete description of your experiments and the data from those experiments. Include the reasons for your choices. Of particular interest is the sequence of experiments you ran and the rationale leading from one experiment to the next.

3. The results of confirmatory experiments.

4. Your conclusions.

5. A critique of your experiments. What went right? What went wrong? How could the experiments be improved? How confident are you in your data?

Project Report

The project report must contain sections 1–5 below. Below is a description of what I will be looking for when I grade the project report. The grade for the project report will be assigned according to the percentages indicated:

1. **Executive Summary** (5%) A one page or less summary of the problem, data generation method, analysis and conclusions. Points will be assigned for conciseness, accuracy and content. (Note that this is a brief summary of items 2–5 below designed to give the essence of the report without the details.)

2. **Problem Description** (10%) Why are you conducting this study? What is the question (or questions) you are trying to answer?

3. **Data Generation** (20%) Is the data generation method you conducted appropriate to answering the questions you want to answer? Is it designed properly? If you conduct a sequence of data generating schemes, are the procedures you follow logical and justified by the previous results? Note that this section must contain a description of the pilot study, its results, and how those results were used in designing the main study.

4. **Analysis** (50%) Is the analysis appropriate and thorough? Does it provide an answer to the questions you asked? Are needed assumptions for statistical methods satisfied? How are missing values or outliers handled? Have you gotten all that can be gotten from the data?

5. **Conclusions** (15%) Appropriateness (are conclusions based on results?), clarity, justification (are arguments well supported?).

6. **Appendix** (0%) The appendix should include well-annotated code for reading and manipulating data, performing analysis, etc. Someone reading your report should be able to understand and reproduce all of your analysis.

Project Presentation

As a team, you will give fifteen-minute presentations on the last day of class. Consider having some photographs in addition to presenting your process, since it's more fun that way.

Drop-off contest

After project presentations we will find a good place to have a helicopter flight contest. Each team will drop their winning helicopter three times and those times will be recorded. A "cost" of +0.2 seconds will be added for each helicopter used in all the experiments required to find the optimal helicopter. This cost is to encourage you to find an optimum in few experiments. (In the past we have had teams make 100s of helicopters!) If, based on three drops, no team is the clear winner based on multiple comparisons based on Fisher's Least Significant Difference (i.e., no correction), then we will continue to drop until we either have a significant winner or a team concedes. Winning is it's own reward.

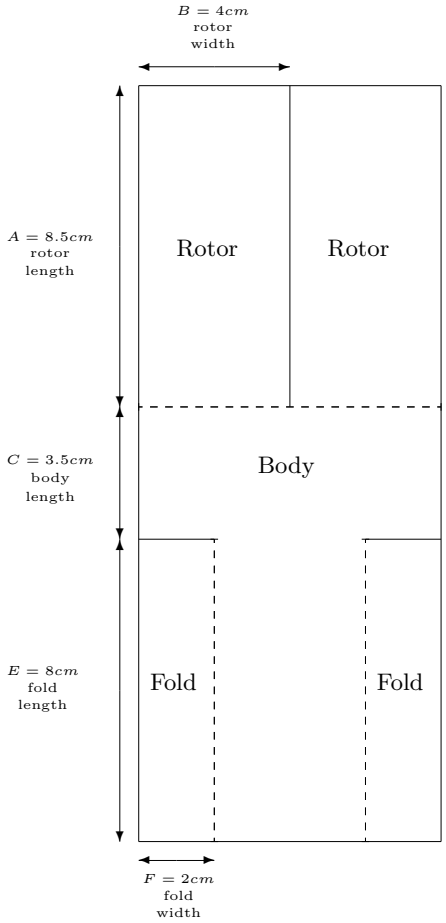

Figure 1: An example of an initial helicopter pattern