Statistical Process Control and Optimization

2024 Spring Final Take-home Exam and Term Project

Note:

(1) Submit your answers in Word or pdf together with an Excel file detailing the calculation procedures of each problem (different sheet for each problem).

(2) You can use any information on the internet to help you answer the problems.

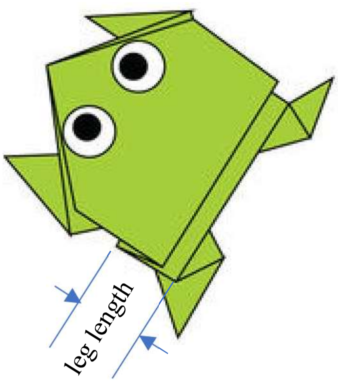
(3) This is not only a term project but also a final take-home exam. You are not allowed to discuss with any human on the earth (絕對不允許與任何人討論). The witness has to be someone not taking this course and can only assist in conducting your experiments.

(4) If you are not certain about the exact meanings of the problems, please make and clearly state your own assumptions and solve the problems under the assumptions. (如果你不確定題目的意思，請自行假設並清楚說明你解題的假設)

(5) Please submit the project reports (in pdf or word format) and excel file to NTU Cool system by **5:30pm 18 June 2024**.

To make a paper jumping frog, follow instructions at https://www.youtube.com/watch?v=oi7oitREUBQ. In this project, we are trying to optimize the performance of this paper frog to jump as far as possible through experimental design and statistical optimization methods.

1. Use only papers of the same quality grade (same weight per square meter). The following three design factors: (a) paper size (two initial levels at height=210mm and height=$\frac{297}{2}$mm) (Note: A4 size is 210mm×297mm) (b) paper height-to-width ratio (two initial levels at width=1/2*height and width=2/5*height) and (c) folded spring leg length (折疊腳寬度 refer to video 5:50~6:00 and define two levels by yourself) are to be used in this project to optimize the jump performance of the paper frog.



2. List at least 3 unwanted noises (nuisances) that could affect the experimental results.
3. With the factors and nuisances, plan a 2^3 factorial experimental design with at least

two replicates of paper frogs and at least two jumps by each frog. Explain how you handle the nuisances with this experimental design.

4. Make the paper frogs required for the experiment and take pictures of the frogs.
5. Perform the experiment tests. You need to provide the details of the experiment procedures including date, time, place, a witness (name and why (s)he is there to witness your experiments; the witness must not be your classmates) and how you measure the jump distance.
6. Perform t-tests to test the significance (α=0.05) of each of the main and interaction effects estimated by the two-level factorial design and build a jumping distance predictive model using the significant effects.
7. Perform ANOVA for the predictive model built in (6). What are the R^2 and adjusted-R^2?
8. Plot the residual Q-Q plots and residual plots for residuals of the model built in (6) with the test data of the two-level factorial experiments. Perform Bartlett's Test and discuss what you observe from the residual plots and the test.
9. Choose an appropriate SN ratio and calculate the SN ratio of the experimental results. Assuming that the smaller interaction effects are insignificant and can be used for testing the statistical significance of main effects and larger interaction effects, perform t-test to determine significant (α=0.05) main and/or interaction effects. Build a predictive model to predict the SN ratio of the performance.
10. Based on results of (6) and (9), what would you suggest the best settings of the three factors in (1) to make an optimum paper jumping frog. How do you predict the performance of this optimum paper frog.
11. Make at least two paper frogs with the optimum settings determined in (10) and verify the predicted performance.
12. Add axial points and center point to the original 2^3 design to form a CCD experimental design. Make the additional paper frogs required for the axial and center design points and take pictures of these additional frogs. There should be at least two replicates of these paper frogs.
13. Perform the experiment tests for the additional frogs made in (12) with at least two jumps by each frog. You need to provide the date, time, place, and a witness (name and why (s)he is there to witness your experiments; could be different from the first witness and again must not be your classmates) and use the same method in (5) to measure the jump distances.
14. Considering possible multicollinearity effects, construct a full quadratic regression models for the jumping distance using all the data from your CCD experiments. Interpret the regression analysis results, including the summary statistics, ANOVA, and factor effects.

15. Based on the interpretation of the regression analysis results of the full quadratic model, recommend and construct a final regression model using only those effects considered significant to predict the jumping distance of the paper frog. Interpret the regression analysis results, including the summary statistics, ANOVA, and factor effects of the recommended model. Compare the model to the model built in (6).
16. For the model in (15), create residual plots and residual Q-Q plots. Compare the plots to those in (8) and discuss what problems you observe from the plots.
17. Considering possible multicollinearity effects, construct a full quadratic regression models for the SN ratio of jumping distance using all the data from your CCD experiments. Interpret the regression analysis results, including the summary statistics, ANOVA, and factor effects.
18. Based on the interpretation of the regression analysis results of the full quadratic model in (17) for the SN ratio, recommend and construct a final regression model using only those effects considered significant to predict the SN ratio of jumping distance. Interpret the regression analysis results, including the summary statistics, ANOVA, and factor effects of the recommended model. Compare the model to the model built in (9).
19. Based on models constructed in (15) and (18), determine the optimum settings of factors to achieve the farthest jump. Predict the performance under the optimum settings.
20. With the optimum settings (19), run verification experiments with at least two replicates to verify the predicted performance. Compare the results with results in (11) and discuss possible problems you observe.