Statistics for Engineering, 4C3/6C3

Question 3, Assignment 7

Kevin Dunn, kevin.dunn@mcmaster.ca

Due date: 20 April 2014, 16:30 (no exceptions)

This question considers a batch reactor process where you convert the raw materials to a low-volume, but very valuable product. There are 3 major factors that can be adjusted:

- **A** = temperature during the batch reaction, Kelvin
- \mathbf{B} = duration of the batch in minutes
- **C** = choice of solvent: hexane or xylene

The response variable is the profit, measured in \$/kg of product. The profit is mostly influenced by the percentage conversion, but the raw material costs and energy consumption do play a role.

There are some constraints on the system:

- A: the batch temperature must lie between 390 to 480K.
- **B**: the batch duration must be longer than 20 minutes, but less than 50 minutes before unwanted side reactions start to consume the product.
- C: either acetone or xylene can be used as the solvent

The 3 factors can be moved anywhere, as long as they obey the constraints. You have a budget of 20 experiments (about \$14,000 per experiment, though your boss prefers you spend less that \$250,000 on this work). Your objective is to find the operating point that gives the highest profit.

Time to clean up and prepare for the next batch takes 3 hours, so 8 experiments, at most, can be run in a 24 hour period.

Your task

You are expected to use all the tools learned in this course to solve this problem; in particular: using clear visualization plots, such as contour or gradient plots and interaction plots, linear models, design of experiments and particularly response surface methods.

A simulation of the process has been computerized, and is available on the course website.

Email me with the following information:

- Your name and student number
- Your partner's name and student number (if you choose to work with someone; you may work alone)
- A name for your group; which will be publicly displayed on the course website; e.g. The Maximizers

I will respond with a login address for your group. Once you sign into the account you will be able to specify the levels of the 3 factors and the server will return the response (i.e. the server will "run" the experiment for you).

Grading and report

Submit a short 4 page report, using Google Drive (preferred) or a PDF shared through Google Drive. The grading for this question will be marked mostly on the **systematic methodology** used to approach the optimum.

Since the cost of each experiment is so high, you must plan your strategy and clearly explain it to your manager (me). You must justify to your manager why you chose *every experiment's conditions*, and what you planned to do with that new result. In particular, you should predict the result of the next experiment before you run it (of course this doesn't apply to the first few experiments). Then use that result in the way you planned, and see if it met your expectations. **Please reread this paragraph again**.

You might realize after you complete this question that you would have done things differently. If so, report what you would have done.

Your final answer must report:

- 1. why you decided to stop with the particular number of experiments you actually ran
- 2. the optimum operating levels for factors A, B, and C that you will recommend to give maximum profit
- 3. give the expected profit at this optimum
- 4. describe why you are convinced you are at or near the optimum, showing a plot of the expected contours at the optimum
- 5. provide a detailed list of things you learned about this process as you were doing the experiments.

The grade you earn for this question will be further adjusted according by adding (or subtracting!) the following amount:

$$5.0 \times \frac{\text{Your optimum} - \text{Baseline}}{\text{True optimum} - \text{Baseline}} - 0.25N + 3.0$$

where N is your number of experiments.

Please note:

- There is error in the response variable in the order of 25 \$/kg; please take this into account.
- For the same levels of A, B and C, the simulation will return different results for different groups.
- Please enter your conditions carefully if you use the wrong settings you will have to work with those results. The operators cannot change the process once you have submitted the settings.
- You must wait 3 hours between each experimental condition; please plan your time accordingly to make sure you finish on time.
- The server will also keep track of and display all your previous experiments on a results sheet.
- Do not try to retroactively justify your experiments. The order in which the experiments were performed is clear from the time stamps on the results sheet. "Trial and error" is not a systematic methodology to approach the optimum, and is wasteful of your budget.

Once you have completed the question, print out the result sheet and submit that with your answer as the final, 5th page. (The true optimum and operating point for the optimum will be be available after the due date).