Chapter 1 Introduction to Designed Experiment

許湘伶

Design and Analysis of Experiments
(Douglas C. Montgomery)
Strategy of Experimentation

- To really understand cause-and-effect relationships in a system you must deliberately (謹慎地) change the input variables to the system and observe the changes in the system output that these changes to the inputs produce.

- Experimentation is a vital (極其重要的) part of the scientific method.

- An experiment is a test or a series of tests.
mechanistic (機械學的) models: the models of such phenomena that follow directly from the physical mechanism. Ex: Ohm’s law $E = IR$

empirical models:
Most problems in science and engineering require observation of the system at work and experimentation to elucidate (說明) information about why and how it works. Well-designed experiments can often lead to a model of system performance.
Experiments are used to study the performance of processes and systems.
The objectives of the experiment may include:

1. Determining **which variables** are most influential on $y$?
2. Determining **where to set the influential $x$’s** s.t.
   - $y$ is almost always near the desired nominal value
   - variability in $y$ is small
   - the effects of $z_1, \ldots, z_p$ are minimized
Strategy of Experimentation (cont.)

- Experiments often involve several factors.

<table>
<thead>
<tr>
<th>The golf experiment</th>
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<tbody>
<tr>
<td>all possible combinations of factor levels are tested</td>
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<tr>
<td>- Type of driver((高爾夫發球時用的)長打杆)</td>
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<tr>
<td>- Type of ball</td>
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<tr>
<td>- Walking vs. riding</td>
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<td>- Type of beverage</td>
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<tr>
<td>- Time of round</td>
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<tr>
<td>- Weather</td>
</tr>
<tr>
<td>- Type of golf spike(高爾夫球釘)</td>
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<td>- Etc, etc, etc⋯</td>
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Strategy of experimentation: to planning (制訂計畫) and conducting (實施) the experiment

1. **best-guess approach:**
   - frequently used in practice
   - often works reasonably well
   - often have great deal of technical or theoretical knowledge of the system
   - **disadvantage:** spend time to guess the initial best-guess; no guarantee (保證) that the best solution has been found
Strategy of Experimentation (cont.)

2 one-factor-at-a-time (OFAT): (in Chapter 5)

- used extensively in practice
- disadvantage: fails to consider interaction between the factors; less efficient
Strategy of Experimentation (cont.)

3. **factorial experiment**: which factors are varied together

- extremely important
- all possible combinations of the factors across their levels are used in the design
- enable to investigate the *individual effects* of each factor and to determine whether the factors *interact*
Figure: $2^2$ factorial design: two factors; each at two levels

(a) Scores from the golf experiment

(b) Comparison of scores leading to the driver effect

(c) Comparison of scores leading to the ball effect

(d) Comparison of scores leading to the ball-driver interaction effect
Factorial designs with several factors

**Figure**: A three-factor factorial experiment

**Figure**: A four-factor factorial experiment
A fractional factorial experiment (部分因子实验) is a variation of the basic factorial design in which only a subset of the runs is used.

Figure: A four-factor fractional factorial experiment
Basic Principles

1. **randomization** (隨機化): Running the trials in random order
   - the allocation of the experimental material
   - the order in which the individual runs of the experiment

2. **replication** (重複)
   - to obtain an estimate of the experimental error
   - to estimate the true mean response for one of the factor levels
   - reflects sources of variability both *between runs and within runs*
   - distinction between replication and repeated measurements

3. **blocking** (集區劃分): a design technique
   - used to reduce the variability transmitted from nuisance factors
     - influence the experimental response but we’re not interested
Guidelines for Designing an Experiment

1. Recognition of (確認) and statement of the problem (Pre-experimental planning)
   Factor screening; Optimization; Confirmation; Discovery; Robustness

2. Selection of the response variable (Pre-experimental planning)

3. Choice of factors, levels, and ranges (Pre-experimental planning)
   Controllable; Uncontrollable; noise factors; cause-and-effect diagram

4. Choice of experimental design

5. Performing the experiment

6. Statistical analysis of the data
   graphical methods; empirical model

7. Conclusions and recommendations (建議)
Guidelines for Designing an Experiment (cont.)

Figure 1.10
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The proper use of statistical techniques in experimentation requires that the experimenter keep the following points in mind:

1. **Use your nonstatistical knowledge of the problem**: knowledge in their fields
2. **Keep the design and analysis as simple as possible**
3. **Recognize the difference between practical and statistical significance**
4. **Experiments are usually iterative**