More for Less: a Comprehensive Experimental Design Approach

M. Sun and H. Fujiiwa*

MINT Center and Department of Mathematics (*Physics and Astronomy)

The University of Alabama

1. Introduction

- Problem: Experimental samples and measurements are often required to reveal a most desirable design based on an analytically unknown relationship between a group of controllable design factors and an objective criterion. How to quickly and effectively determine what samples to make and what is a most desirable design?
- Examples of controllable design factors:
  - material's magnetic, physical, or chemical parameters
  - material types, material composition
  - sample’s geometric parameters
  - thickness, surface roughness, number of layers

2. Design Methods

- Conventional optimization search algorithms are not applicable due to lack of analytical form of the objective function.
- Objective: Make a relatively small number of experimental samples and measurements to identify a desirable design.

3. Balanced Designs

- Role of expert knowledge within our design methodology:
- A basic mathematical tool for achieving statistically balanced experiment design factors. For example, Ex1b is partially and weakly coordinated SR, NC, NL.

4. Example of Design Layout

<table>
<thead>
<tr>
<th>Design factors</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>thickness, annealing temperature, annealing time</td>
<td></td>
</tr>
</tbody>
</table>

Effective design layout based on the orthogonal array:

<table>
<thead>
<tr>
<th>sample</th>
<th>thickness</th>
<th>annealing temperature</th>
<th>annealing time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>low</td>
<td>short</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>high</td>
<td>long</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>high</td>
<td>short</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>low</td>
<td>long</td>
<td></td>
</tr>
</tbody>
</table>

5. Description of Our Design Methodology

- Role of expert knowledge within our design methodology:
- determination of NL (levels of each design factor) definition of levels of each design factor
- determination of possible interacting factors
- verification of predicted best designs.

- Analysis of the balanced experimental data:
- Basic statistical analysis of data — For each factor’s response data, we can calculate average response, range of response, rank of significance. For the overall data, we can determine the best sample that has been measured. We can also predict a best sample that may not have been measured. We can also detect level of correlation/interaction between any two design factors.

6. Synthetic Test Examples

- Example 1: its 7 objective functions are specially designed to show various degrees of interactions among the controllable design factors. For example, Ex1b is partially and weakly coupled among the factors.
- Example 2: Most of its 13 objective functions are taken from the optimization literature, which are widely regarded as reliable and difficult test examples. For example, Griewank’s function is our Ex2k with dim(x) = 10, defined as follows.

7. Conclusions

- Balanced designs before trials offer a lot more useful data set for further analysis.
- Balanced designs before trials offer economic, desirable, and timely solutions to problems that experimental scientists and engineers routinely face in their research.
- Balanced designs before trials cost less.

References


For more information and reprints contact:
E-mail: msun@uab.edu