
Modern DoE: JMP's Custom Designer

David Meintrup

STATCON, Hochschule Ingolstadt

Our View of the World:

- **General Model Assumption:**

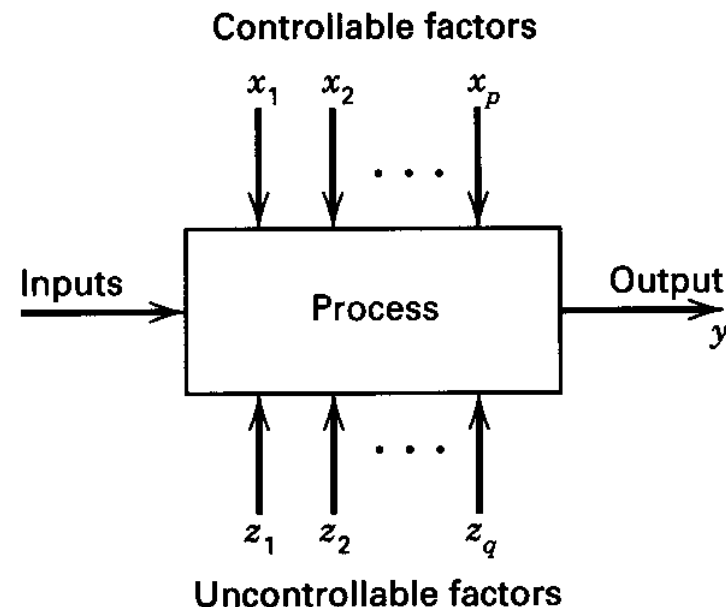
$$Y = f(x_1, \dots, x_p) + \varepsilon$$

- **General Goal:**

find function $f(x_1, \dots, x_p)$

- **General strategy:**

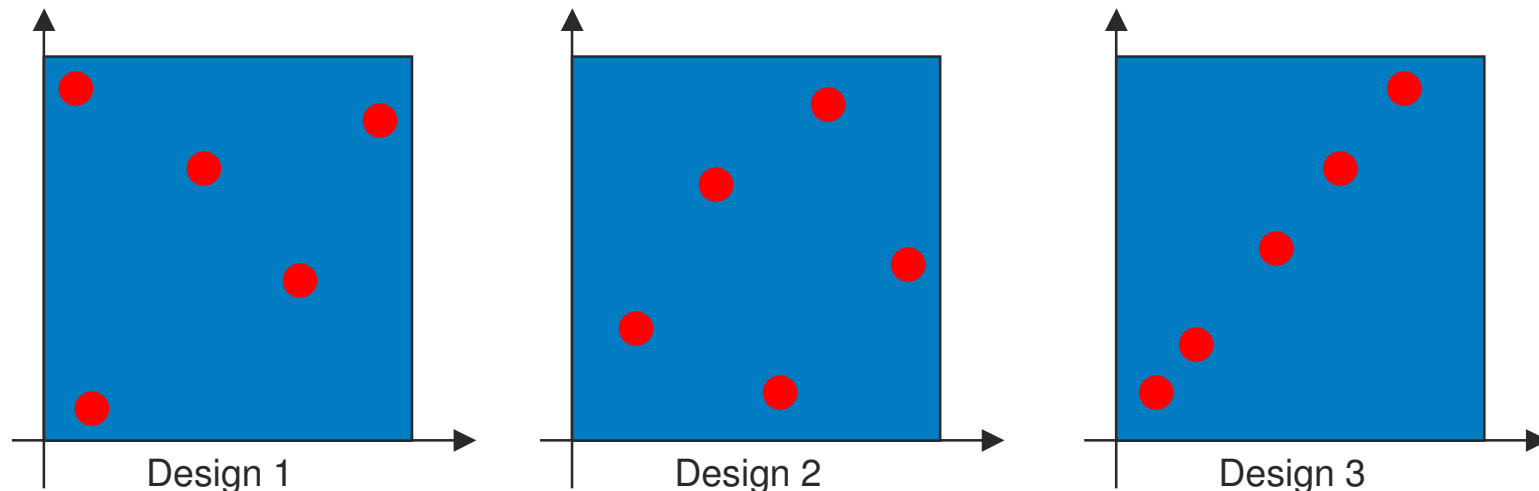
- Perform a **set of experiments**: set Xs, measure Y
- **Fit Model** $f(x_1, \dots, x_p)$ to result of experiments



What is Design of Experiments (DoE) ?

Suppose for simplicity $Y = f(X1, X2) + \epsilon$.

Where should we put runs (points), i.e. how do you set the Xs ?



DoE: use statistical considerations to choose runs

Design Problem – Design Opportunity!

Classic Designs:

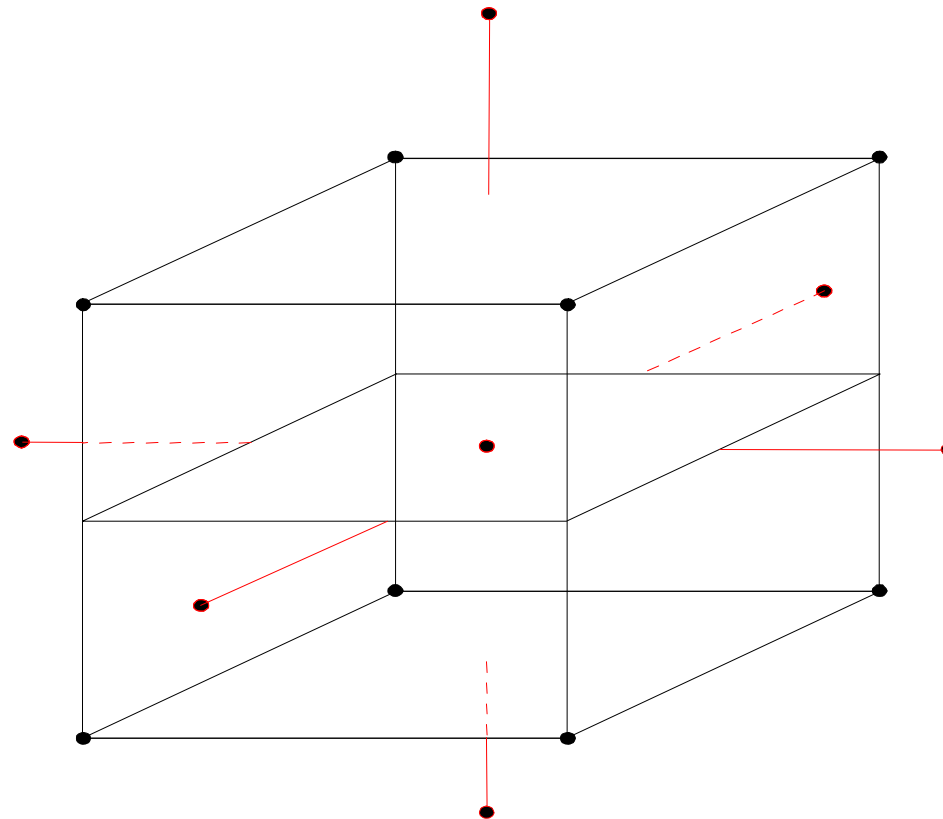
Factorial Designs (1920s) :

- **Full Factorial Designs**
- **Fractional Factorial Designs**
- **Typical use: screening for important factors**

Response Surface Designs (1940s):

- **Central Composite Design (CCD)**
- **Box – Behnken Design**
- **Typical use: optimization**

Central Composite Design



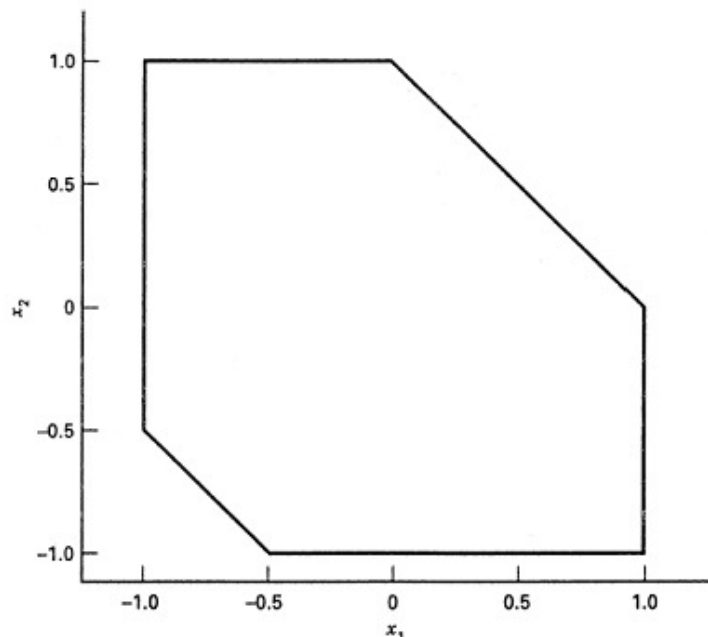
Reasons why you can't use classic designs

- Irregular experimental region
 - Constraints
- Nonstandard model
 - Including higher order terms due to subject knowledge
 - Including categorical factors
- Unusual sample size or blocking requirements

In these situations we use computer-generated (“optimal”) designs

Constrained design region:

Example*: amount of adhesive and cure temperature



Constraints:

$$-1.5 \leq x_1 + x_2$$

$$x_1 + x_2 \leq 1$$

*Montgomery, D.C., „Design and Analysis of Experiments“, Wiley.

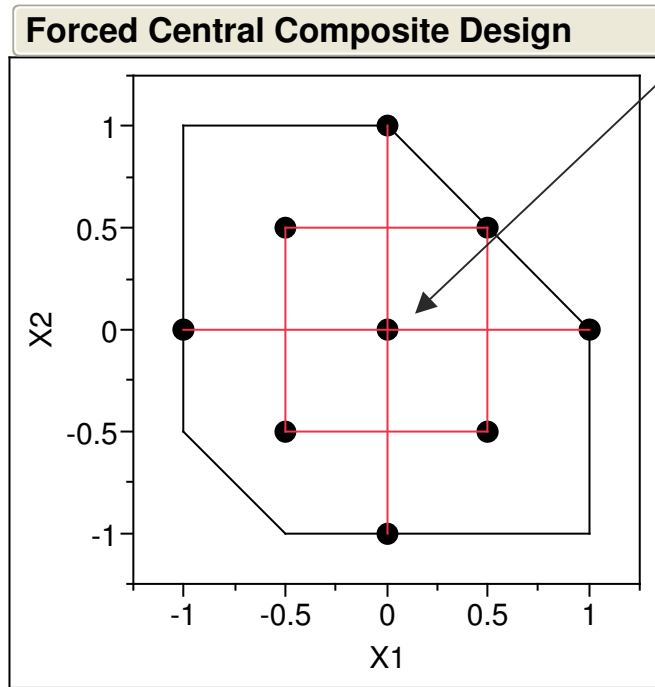
Strategies for solution:

- “Force” a standard design into the experimental region
 - Will lead to loss of information
 - If you have no other choice only
- Generate a unique design just for this particular situation
 - **D-optimal** designs: minimize the volume of the joint confidence region on the model parameters
 - **I-optimal** designs: minimize the average scaled prediction variance over the design region

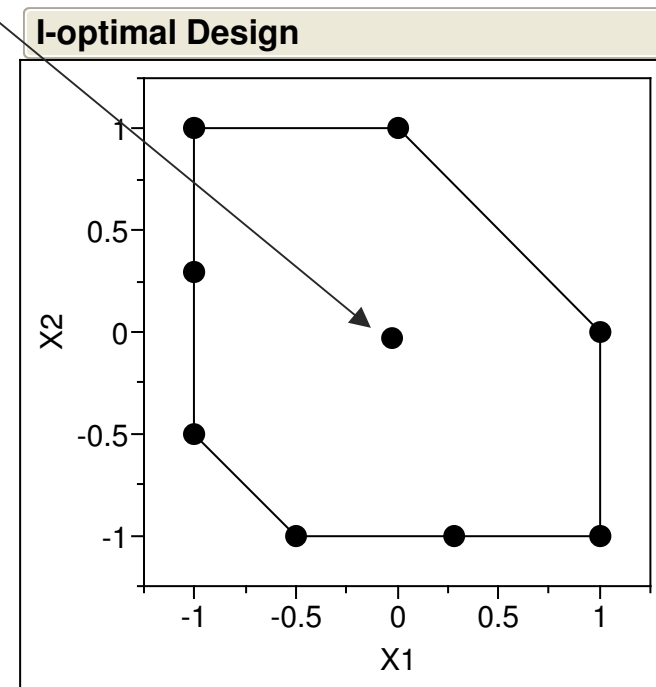
Fit the design to the problem, not the problem to the design

Design Comparison – Design Points

4 replicates

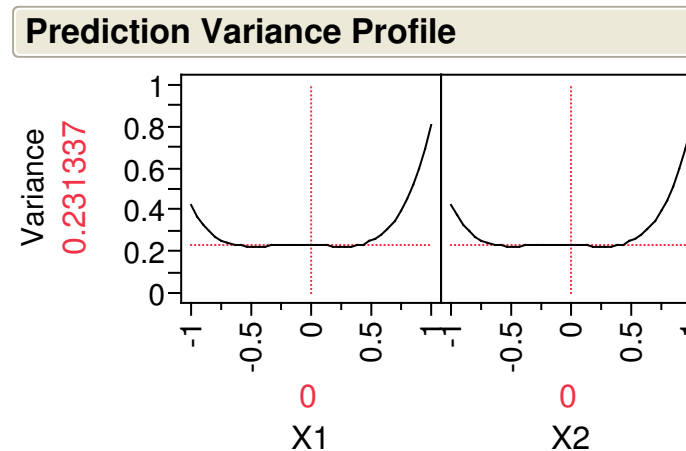
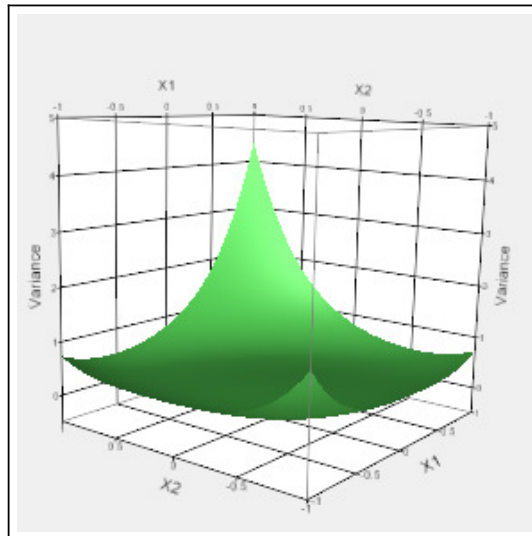


Forced CCD Design Points



I-optimal Design Points

Design Comparison – I-optimal Variance Profile



- Relative efficiency of inscribed CCD compared to the optimal design approx. 48%.
- About twice as many runs needed in CCD for same precision

Technical and Practical Advantages of JMP's Custom Designer

- Process variables in a mixture experiment.
- Screening with flexible sample and block sizes.
- Response surface models with categorical factors.
- Avoiding unworkable factor combinations.
- Optimal designs with random effects.

- **JMP – Demo: Custom Designer**