DOE Perspectives

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Experiment Strategies

"I Want Optimal Results!"

You use DOE to find a Sweet Spot — a combination of your factors that will produce an excellent product. You find this Sweet Spot using a model that predicts product performance for any combination of factors that interest you.

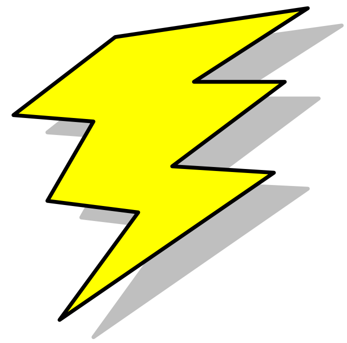
I-Optimal designs can produce similar confidence limits to conventional designs, but with fewer runs.

You need your model to predict as accurately and precisely as possible. You make your measurements carefully and run replicates to insure that your predictions are accurate and precise. You also need to consider your experiment design — it has a direct effect on the precision of your predictions.

Trials in designed experiments are well spread out from each other. Spreading the points out makes it possible to fit a model accurately. Points can be spread out in different ways. Classic designs spread the points out in space. I-Optimal designs spread the points out to give the minimum average variance of prediction.

What on Earth is the minimum average variance of prediction? Variance is the square of the standard deviation. Standard deviation is a measure of the width of a bell shaped pile of data and is used to calculate confidence limits. Confidence limits tell you how good your prediction is. By minimizing the average variance of prediction, I-Optimal designs attempt to provide you with the smallest possible confidence limits on your predictions.

Suppose you are printing money and you want to know how fast you can run the press and how thick your ink should be to produce the sharpest image of Benjamin Franklin. You



use a designed experiment to build a model to predict image sharpness. At a speed of 50 feet per minute and an ink thickness of 300 cps, your model predicts the image sharpness to be 75. That's wonderful — the kind of sharpness you wanted. Then you look at the confidence limits — plus and minus 25. So you can expect that if you run the press at 50 feet per minute with an ink viscosity of 300 cps, you will get a sharpness from 50 to 100. It would certainly be nicer to have confidence limits of plus and minus 5. How can you get smaller confidence limits?

The first step to

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achieving smaller confidence limits is to reduce the variation in your measurements. Calibrate your tools, train the people making the measurements to use proper technique, use the best measuring instruments you can afford, and use great care to make the best possible measurements. The second step is to use a design that will provide small confidence limits. An I-Optimal design will produce the smallest confidence limits on average.

Table 1 shows a conventional experiment design for a quadratic model with 2-factor interactions. It has 20 trials, 5 of which have 2 replicates each. Table 2 shows an I-Optimal design in 20 trials, 5 of which have 2 replicates each. Clearly the points are spread out differently.

If we standardize our standard deviation to 1 and our t value to 2.57, we can directly compare the effect each design has on the confidence limits for predictions. For a randomly chosen point, the conventional design had confidence limits of plus and minus 2.96, while the I-Optimal design had confidence limits of plus and minus 1.86. The average confidence limits for 1000 randomly selected points were plus and minus 2.23 for the conventional design, and plus and minus 1.45 for the I-Optimal design. The I-Optimal design produces better confidence limits on predictions.

I-Optimal designs produce smaller confidence limits than conventional designs with the same number of runs. Because of this, I-Optimal designs can produce similar confidence limits to conventional designs, but with fewer runs.

The next time you perform an experiment, use the same care you normally use to insure small confidence limits, and use an I-Optimal design to get small confidence limits with fewer runs.

Trial	X1	X2	X3	X4
20	-1	0	-1	1
3	1	-1	1	-1
4	-1	1	1	-1
8	-1	1	1	1
9	1	1	1	0
1	-1	-1	-1	-1
14	1	0	0	1
1	-1	-1	-1	-1
2	1	1	-1	-1
11	-1	1	-1	0
2	1	1	-1	-1
15	0	1	0	1
4	-1	1	1	-1
10	1	-1	-1	0
12	-1	-1	1	0
19	-1	0	1	-1
3	1	-1	1	-1
5	-1	-1	-1	1
7	1	-1	1	1
13	0	0	1	1
17	0	1	-1	-1
18	1	-1	0	-1
6	1	1	-1	1
16	0	-1	-1	1
5	-1	-1	-1	1

Table 1 — Conventional Experiment Design

Trial	X1	X2	X3	X4
1	-1	-0.39	1	-0.45
2	-1	-0.39	1	-0.45
3	-0.01	-1	0.01	-0.1
4	-0.01	-1	0.01	-0.1
5	1	0.3	0.04	0.88
6	1	0.3	0.04	0.88
7	1	-1	-1	0.37
8	1	-1	-1	0.37
9	-0.06	0.12	-0.08	0
10	-0.06	0.12	-0.08	0
11	0.04	-0.01	1	0.43
12	0	-0.01	-1	-1
13	1	1	1	-0.03
14	-1	-1	0.19	1
15	1	-0.15	-0.05	-1
16	-1	1	-1	0
17	-1	-1	-1	-1
18	1	-1	1	-1
19	1	-1	1	1
20	-1	-0.25	-1	1
21	-1	1	0.04	-1
22	-0.03	1	1	-1
23	-1	1	1	1
24	1	1	-1	-0.92
25	0.34	1	-1	1

Table 2 — I-Optimal Experiment Design