Today, we will:

- Do a review example problem – Experimental design and Taguchi arrays
- Review the pdf module: **Taguchi Orthogonal Arrays**
- Review the pdf module: **Response Surface Methodology (RSM)**, and do examples

Example - Continued from last time.

Given: A toy gun that shoots Nerf bullets is being designed. The engineers want to maximize the distance traveled by the bullet. Three parameters are to be varied:

- *a* = spring constant
- *b* = weight of the bullet
- *c* = diameter of the bullet

The engineers decide to test 4 levels for each of these 3 parameters.

(*a*) To do: Calculate how many runs are required for a full-factorial analysis.

Solution:

$$N = L^P = 4^3 = \boxed{64}$$

(*b*) To do: Design a Taguchi array such that each level of each parameter appears twice.

Solution:

We need 8 runs since we have four levels, and we want each level of each parameter to appear twice; thus, $N = 4 \times 2 = \boxed{8}$ for a fractional factorial design array.

We come up with the following Taguchi design array:

run #	*a*	*b*	*c*
1	1	1	1
2	1	2	4
3	2	3	3
4	2	4	2
5	3	1	2
6	3	2	3
7	4	3	1
8	4	4	4

Q. Is this a proper Taguchi array?

A. Yes – it meets both criteria

- Each level of each parameter appears the same # of times (2 times)
- No unnecessary repeats

Q. Is this an orthogonal array?

A. No → For an orthogonal array, for each level of each parameter, all levels of all the other parameters must appear at least once. [Eg. b=2 → c= 4,3. missing c=1 & c=2.]

Has 16 runs

[See the orthogonal array for this case (L=4, P=3) on the course website]

(*c*) To do: Now that the Taguchi design array is set up, experiments are performed, with the following results. Calculate the level averages, and determine which levels are optimum.

run #	*a*	*b*	*c*	*X* (m)	
1	1	1	1	5.5	$\leftarrow X_1$
2	1	2	4	6.2	$\leftarrow X_2$
3	2	3	3	6.0	$\leftarrow X_3$
4	2	4	2	7.3	$\leftarrow X_4$
5	3	1	2	7.6	$\leftarrow X_5$
6	3	2	3	8.1	$\leftarrow X_6$
7	$\boxed{4}$	$\boxed{3}$	$\boxed{1}$	9.7	$\leftarrow X_7$
8	4	4	4	7.2	$\leftarrow X_8$

e.g. $\bar{X}_{c_4} = (X_2 + X_8)/2$

Solution: [See also Excel file on the course website – **Example_Taguchi_array.xls**]

$\boxed{\text{Q.}}$ How many level averages do we need?

$\boxed{\text{A.}}$ We have 4 levels of each parameter
We have 3 parameters
$\therefore$ Need $4 \times 3 = \boxed{12 \text{ level averages}}$

Examples: (color coded)

$$\bar{X}_{a_1} = (X_1 + X_2)/2 = (5.5 + 6.2)/2 = \boxed{5.85 = \bar{X}_{a_1}}$$

$$\bar{X}_{b_3} = (X_3 + X_7)/2 = (6.0 + 9.7)/2 = \boxed{7.85 = \bar{X}_{b_3}}$$

$$\bar{X}_{c_4} = (X_2 + X_8)/2 = (6.2 + 7.2)/2 = \boxed{6.70 = \bar{X}_{c_4}}$$

⋮ etc. Calculate all 12 level averages

See Excel file → Bottom line to maximize X,

- Use level 4 of parameter a [largest spring constant]
- Use level 3 of parameter b [medium weight]
- Use level 1 of parameter c [smallest diameter]

(*d*) To do: Recommend follow-up experiments if only two parameters can be tested.

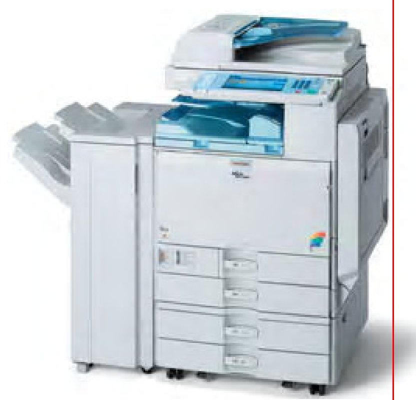
Solution: Note: A confirmation experiment is not necessary since this is run $\boxed{7}$!

Since c has the smallest effect on X, we test only a & b

- Test larger values of a (spring constant)
- Test b around level 3 (weight)

Example: Experimental design using RSM

Given: Cory uses RSM to increase the performance (speed) of a photocopier machine. He changes three parameters simultaneously, but in no particular pattern. He takes enough data to determine the direction of steepest ascent. Here are the variables:



- *a*, the tension on a belt drive, varied from 400 to 550 N.
- *b*, the volume flow rate of cooling air supplied, varied from 1.8 to 4.5 L/min.
- *c*, the voltage supplied to a component, varied from 20 to 35 V.

To do:

(***a***) Calculate the *range* of coded variable x_2 corresponding to physical variable *b*.

Ans: $\boxed{-1 \text{ to } 1}$ [All coded variables are dimensionless; range from -1 to 1]

(***b***) Calculate coded variable x_1 corresponding to physical variable $a = 475$ N.

Solution:

$$a_{mid} = \frac{400 + 550}{2} = 475$$

$$a_{range} = 550 - 400 = 150$$

- Method A → use the equation

$$X_1 = 2\left(\frac{a - a_{mid}}{a_{range}}\right) = 2\left(\frac{475 - 475}{150}\right) = \boxed{0}$$

Answer

- Method B → Linearly interpolate

		min			middle			max
Scale for a:	a	400	425	450	475	500	525	550
Scale for x_1	X_1	-1			0			1

OR, linearly interpolate like this:

	a	X_1
min →	400	-1
our value →	475	$\square$
max →	550	1

→ Linear interpolation yields $\boxed{X_1 = 0}$