Taguchi Methods

- Genichi Taguchi has been identified with the advent of what has come to be termed quality engineering.

- The goal of quality engineering is to move quality improvement efforts upstream from the production phase to the product/process design stage (off-line).

- As his loss function demonstrates, his main concern is deviation of a characteristic from its nominal value. Uncontrollable factors (noise) are often responsible for this deviation and, therefore, Taguchi's approach to experimental design has as its goal the design of products/process that are robust to these noise factors.

Taguchi’s three stage design process

- System Design - create prototype product and process to produce it.

- Parameter Design - find settings of process and product parameters which minimize variability.

- Tolerance Design - tradeoff between loss to consumer and manufacturing costs

Signal to Noise Ratios

- In the parameter design stage Taguchi makes use of designed experiments and signal to noise ratios to determine the optimal parameter settings.

- The signal to noise ratios are derived from the Taguchi loss function.

- While Taguchi has proposed a large number of signal to noise ratios three are the most widely used:

Nominal is Best: $SN_N = 10\log\left(\frac{\bar{y}^2}{s^2}\right)$

Larger is Better: $SN_L = -10\log\left(\frac{\sum_{i=1}^{n} 1/y_i^2}{n}\right)$

Smaller is Better: $SN_S = -10\log\left(\frac{\sum_{i=1}^{n} y_i^2}{n}\right)$

Experimental Design

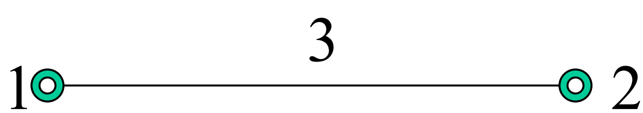
- Taguchi has designed a number of orthogonal arrays to aid in the development of experiments
- These arrays are essentially balanced fractional factorial designs.
- He suggests using two array matrices for each designed experiment.
- The inner array is used to study the effects of the design parameters we wish to study.
- An outer array is used to model the noise factors that may impact the performance of the product in the field.

- Two of the Taguchi's simpler Orthogonal arrays are:

$L_4(2^3)$ and the $L_8(2^7)$:

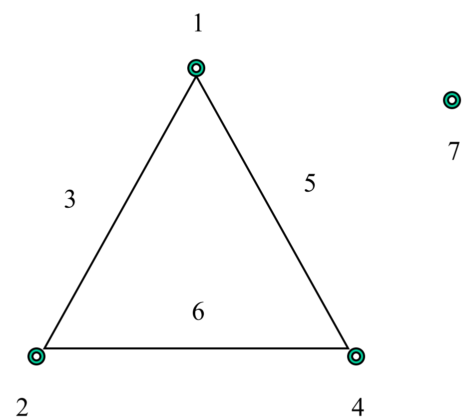
$L_4(2^3)$

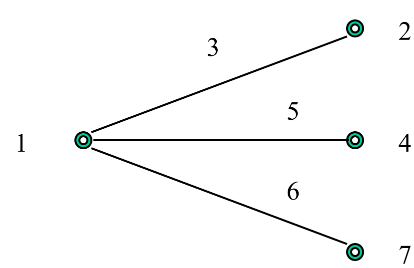
	Factors		
run	1	2	3
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1



- The $L_8(2^7)$ Orthogonal Array and its Linear Graphs

	Factors						
Run	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2





Example

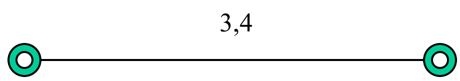
- In 1987 Taguchi published a paper in *quality progress* giving an example of his approach. The objective was to maximize the pull-off force of a connector to a nylon tube for an automotive application so SN_L . The factors studied and there levels are tabled below along with the results:

Design Factors		**Levels**		
A	Interference	Low	Medium	High
B	Connector wall thickness	Thin	Medium	Thick
C	Insertion depth	Shallow	Medium	Deep
D	Percent adhesive	Low	Medium	High
Noise Factors		**Levels**		
E	Conditioning Time	24h	120h	
F	Conditioning Temp	72°	150°	
G	Conditioning Humidity	25%	75%	

Outer Array (L_8)				E F G	1 1 1	1 1 2	1 2 1	1 2 2	2 1 1	2 1 2	2 2 1	2 2 2		
Inner Array (L_9)													Responses	
Run	A	B	C	D									Ave	SN_l
1	1	1	1	1	15.6	9.5	16.9	19.9	19.6	19.6	20.0	19.1	17.5	24.0
2	1	2	2	2	15.0	16.2	19.4	19.2	19.7	19.8	24.2	21.9	19.4	25.5
3	1	3	3	3	16.3	16.7	19.1	15.6	22.6	18.2	23.3	20.4	19.0	25.3
4	2	1	2	3	18.3	17.4	18.9	18.6	21.0	18.9	23.2	24.7	20.1	25.9
5	2	2	3	1	19.7	18.6	19.4	25.1	25.6	21.4	27.5	25.3	22.8	26.9
6	2	3	1	2	16.2	16.3	20.0	19.8	14.7	19.6	22.5	24.7	19.2	25.3
7	3	1	3	2	16.4	19.1	18.4	23.6	16.8	18.6	24.3	21.6	19.8	25.7
8	3	2	1	3	14.2	15.6	15.1	16.8	17.8	19.6	23.2	24.2	18.3	24.8
9	3	3	2	1	16.1	19.9	19.3	17.3	23.1	22.7	22.6	28.6	21.2	26.2

Taguchi used the L_8 design to model the noise factors and the $L_9(3^4)$ series of orthogonal arrays to model the design factors. The L_9 design is as follows:

	Factors			
Run	***1***	***2***	***3***	***4***
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

1  2