

Introduction to Experimental Design


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Basic Notions in Design of Experiments

- Response: what you want to measure.
- Factor: what affects the response.
- Level: value of a factor.

	Factors			Response
	CPU Clock Frequency (MHz)	Number of CPUs	Main Memory (MB)	Benchmark Execution Time (sec)
	550	1	128	25
	750	1	128	32
	1000	1	128	48
	550	2	128	19
	750	2	128	14
	1000	2	128	10
	550	1	256	23
	750	1	256	29
	1000	1	256	45

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Basic Notions in Design of Experiments

- Primary Factors: those whose effects need to be quantified.
- Secondary factors: not interested in quantifying effects.
- Replication: repetition of some or all of the experiments.
- Design: (no. of experiments, factor level combination, no. of replications per experiments).

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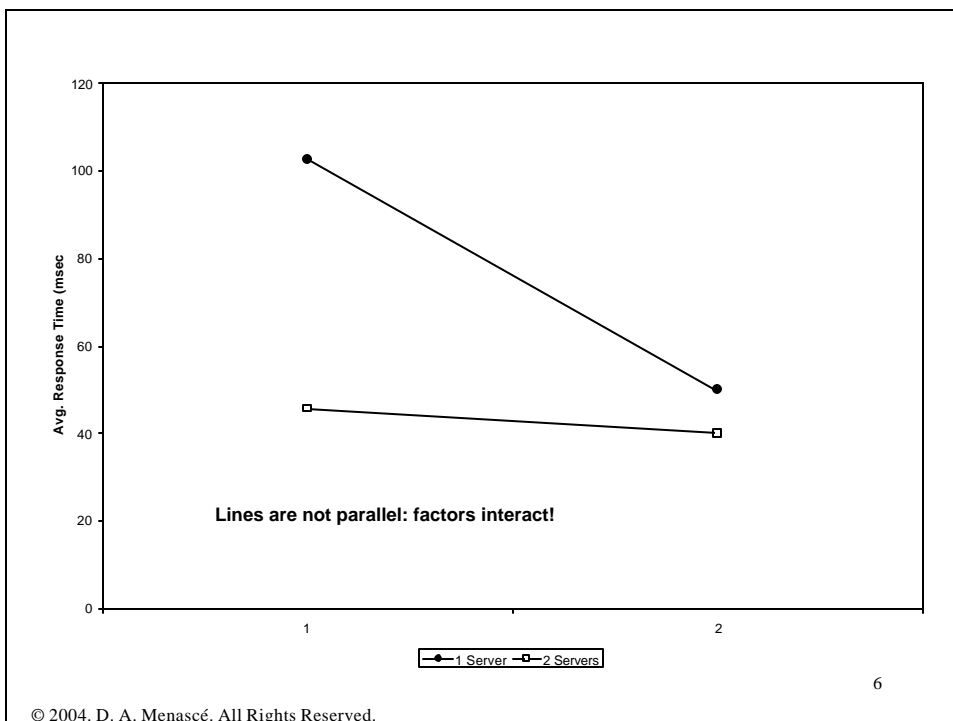
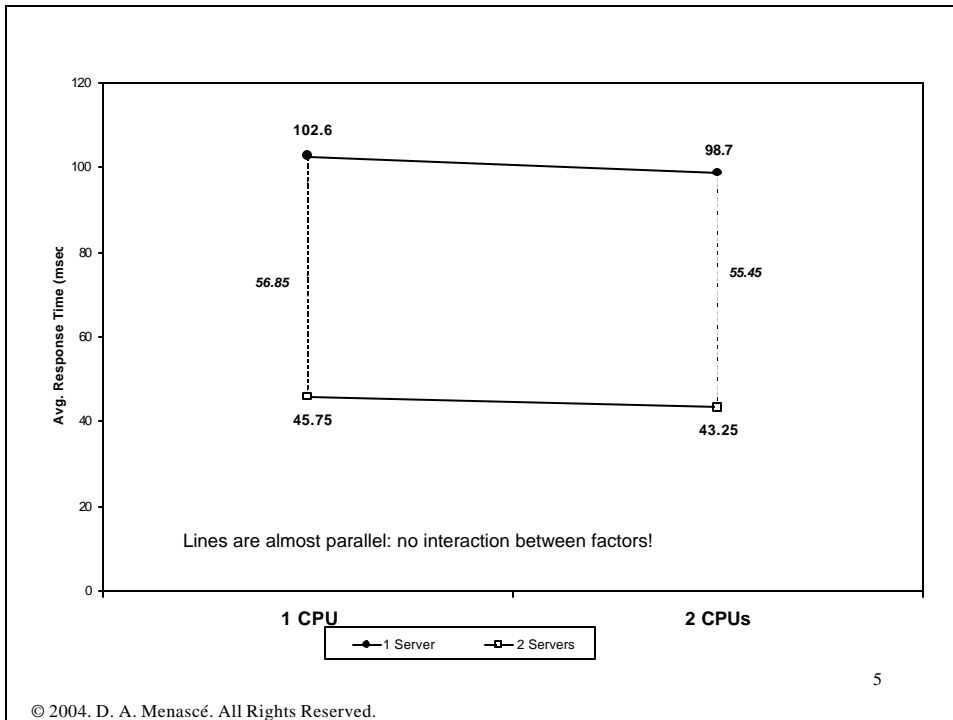
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Basic Notions in Design of Experiments

- Experimental unit: entity used for an experiment.
- Interaction: Factors A and B interact if the effect of one depends upon the level of the other.

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Common Errors in Experimentation

- Variation due to experimental error is ignored.
- Important parameters are not controlled.
- Effects of different factors not isolated.
- Simple one-factor-at-a-time designs.
- Interactions are ignored.
- Too many experiments are conducted.

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Types of Experimental Designs

- Simple Designs:
 - Start with base combination of factor levels and vary one factor at a time.

	Factors			Response
	CPU Clock Frequency (MHz)	Number of CPUs	Main Memory (MB)	Benchmark Execution Time (sec)
Levels	550	1	128	25.0
	750	1	128	32.0
	1000	1	128	48.0
	550	2	128	19.0
	750	2	128	13.5
	1000	2	128	10.0
	550	1	256	23.0
	750	1	256	29.0
	1000	1	256	45.0
	550	2	256	16.5
	750	2	256	11.8
	1000	2	256	8.8

$$n = 1 + \sum_{i=1}^k (n_i - 1)$$

factors

exp.

levels of factor i.

$$n = 1 + (3 - 1) + (2 - 1) + (2 - 1) = 5$$

Not good if factors interact.

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Types of Experimental Designs

- Full Factorial Design:
 - Uses all possible combinations of all levels of all factors.

	Factors			Response
	CPU Clock Frequency (MHz)	Number of CPUs	Main Memory (MB)	Benchmark Execution Time (sec)
Levels	550	1	128	25.0
	750	1	128	32.0
	1000	1	128	48.0
	550	2	128	19.0
	750	2	128	13.5
	1000	2	128	10.0
	550	1	256	23.0
	750	1	256	29.0
	1000	1	256	45.0
	550	2	256	16.5
	750	2	256	11.8
	1000	2	256	8.8

$$n = \prod_{i=1}^k n_i$$

$$n = 3 * 2 * 2 = 12$$

Too costly!

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Types of Experimental Designs

- Reducing Cost of Full Factorial Design:
 - Reduce the no. of levels of each factor. If all factor have 2 levels, we have a 2^k factorial design.
 - Reduce the number of factors.
 - Use fractional factorial designs.

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Types of Experimental Designs

- Fractional Factorial Design:

- Use a fraction of the full factorial design.

	Factors		Response
	CPU Clock Frequency (MHz)	Number of CPUs	Benchmark Execution Time (sec)
Levels	550	1	25.0
	750	1	32.0
	1000	1	48.0
	550	2	19.0
	750	2	13.5
	1000	2	10.0

$$n = \prod_{i=1}^{k-p} n_i$$

$$n=3*2=6$$

Some interactions among factors may be lost!

The factor memory size was eliminated.

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Types of Factors

- Discrete: only a finite number of levels.
 - e.g., number of CPUs
 - HTTP Keep-Alive (enabled or disabled)
- Continuous: the factor can take on values from a continuous range.
 - e.g., TCP connection timeout
 - working set size

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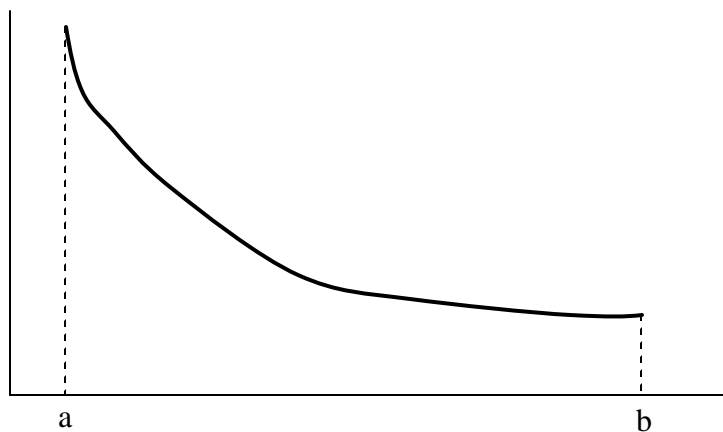
Dealing with Continuous Factors

- Discretize : pick a set of values in the range of possible values.
- Which values to pick?
 - Run experiments and do a binary search on the range guided by a variation threshold

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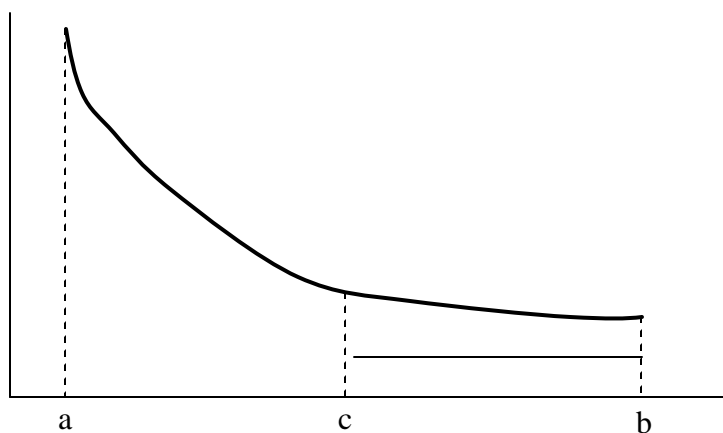
Discretizing a Continuous Factor



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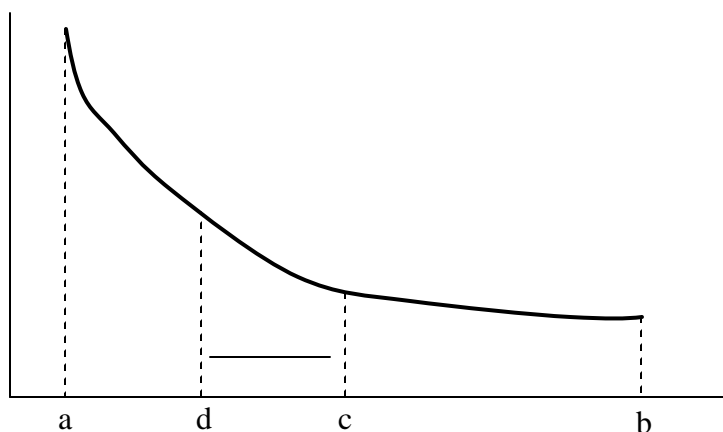
Discretizing a Continuous Factor



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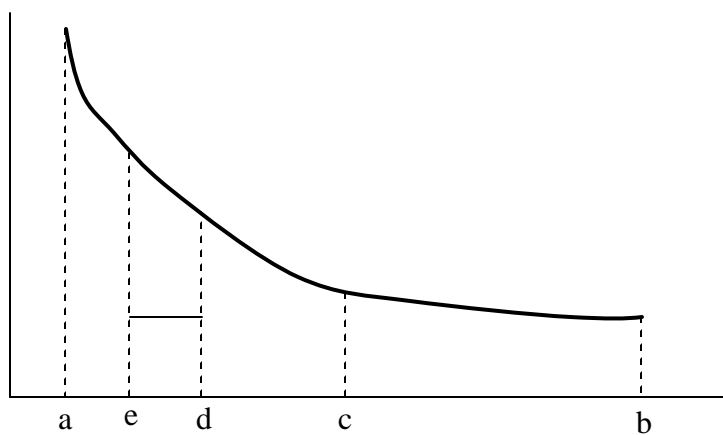
Discretizing a Continuous Factor



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Discretizing a Continuous Factor



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