Introduction to Experimental Design

Prof. Daniel A. Menascé
Dept. of Computer Science
George Mason University

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

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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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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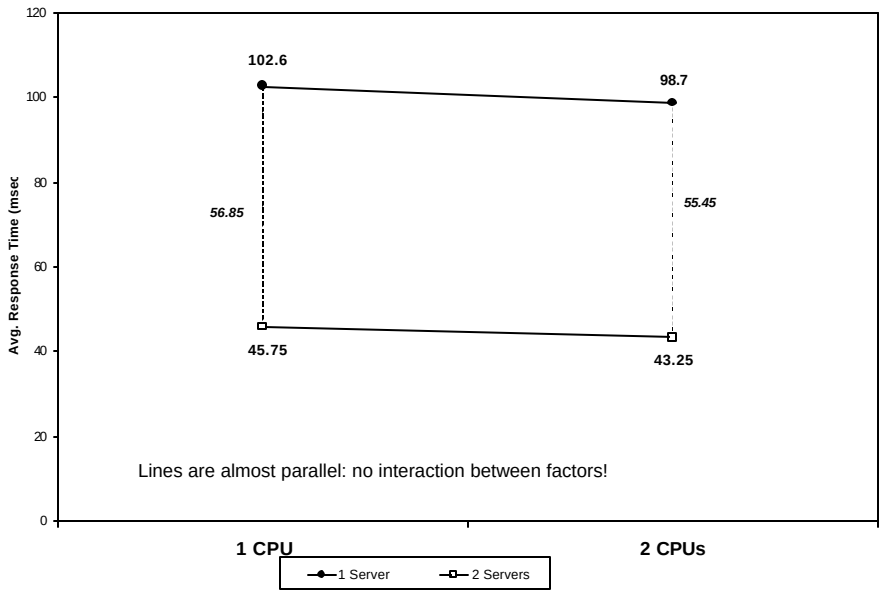

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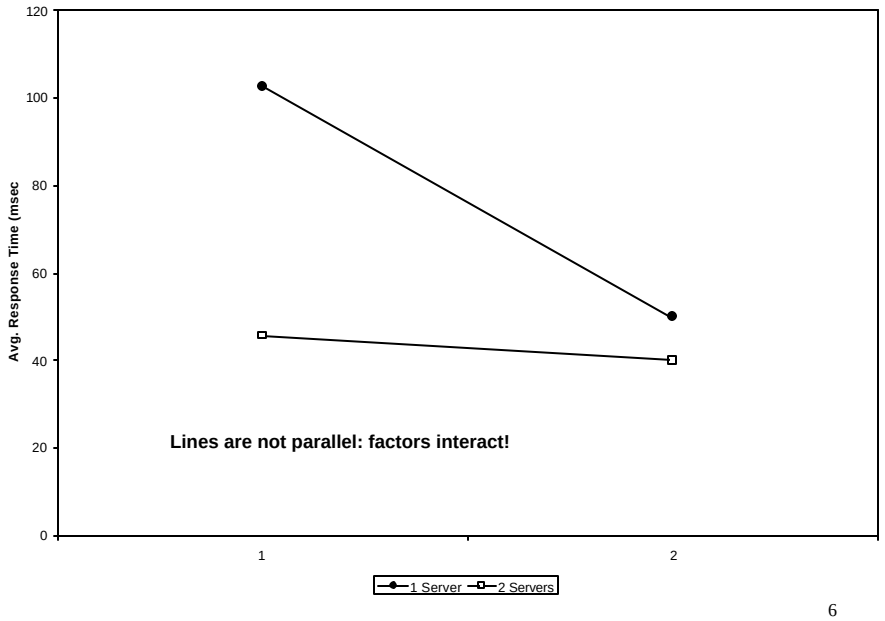

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Common Errors in Experimentation

- 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

factors

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

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.

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	750	1	256	29.0
	1000	1	256	45.0
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	750	2	256	11.8
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$$n = \prod_{i=1}^{k} n_i$$

n=3*2*2=12

Too costly!

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.

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

The factor memory size was eliminated.

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

n=3*2=6

Some interactions among factors may be lost!

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

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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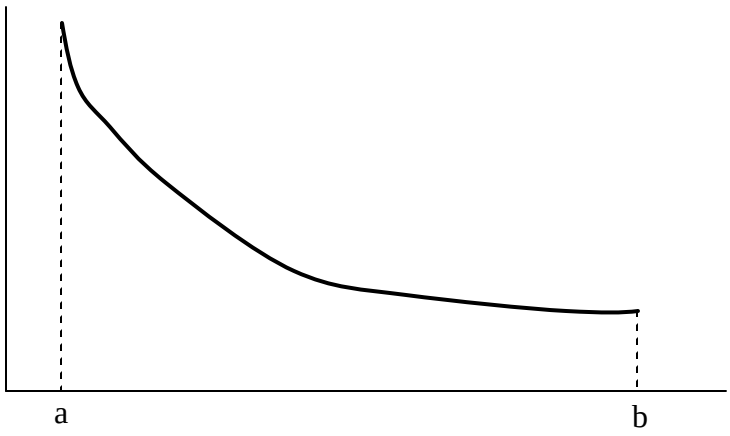
Discretizing a Continuous Factor



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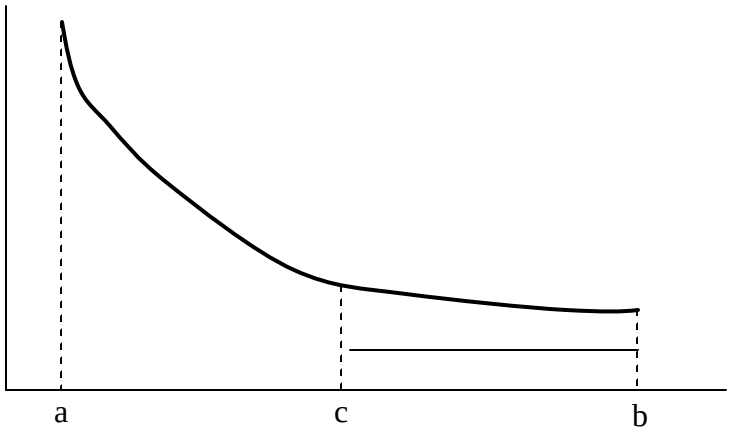
Discretizing a Continuous Factor



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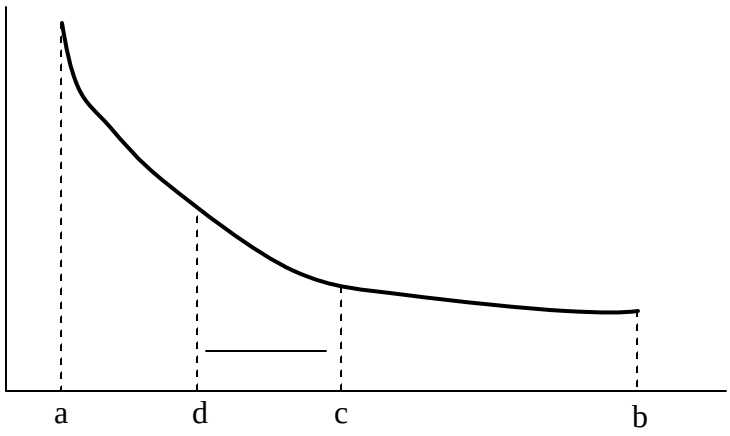
Discretizing a Continuous Factor



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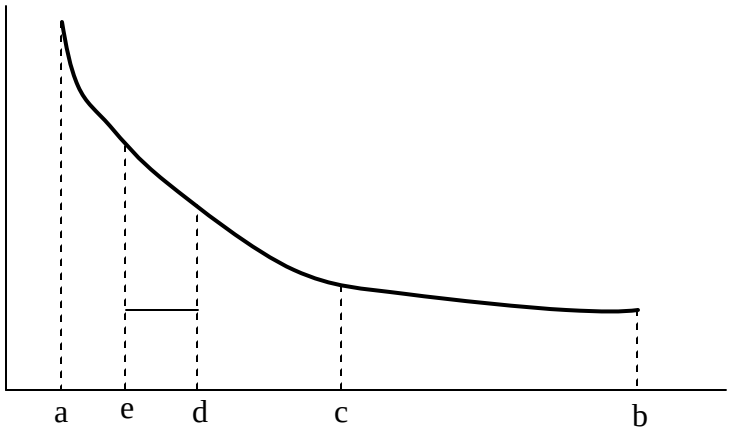
Discretizing a Continuous Factor



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