

# Introduction to Experimental Design

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These slides are available on-line at:

<http://www.cse.wustl.edu/~jain/cse567-08/>



- What is experimental design?
- Terminology
- Common mistakes
- Sample designs

## Experimental Design and Analysis

### How to:

- ❑ Design a proper set of experiments for measurement or simulation.
- ❑ Develop a model that best describes the data obtained.
- ❑ Estimate the contribution of each alternative to the performance.
- ❑ Isolate the measurement errors.
- ❑ Estimate confidence intervals for model parameters.
- ❑ Check if the alternatives are significantly different.
- ❑ Check if the model is adequate.

## Example

### Personal workstation design

1. Processor: 68000, Z80, or 8086.
2. Memory size: 512K, 2M, or 8M bytes
3. Number of Disks: One, two, three, or four
4. Workload: Secretarial, managerial, or scientific.
5. User education: High school, college, or post-graduate level.

Five **Factors** at 3x3x4x3x3 **levels**

## Cartoon

### WIT OF THE WORLD



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## Terminology

- ❑ **Response Variable:** Outcome.  
E.g., throughput, response time
- ❑ **Factors:** Variables that affect the response variable.  
E.g., CPU type, memory size, number of disk drives, workload used, and user's educational level.  
Also called predictor variables or predictors.
- ❑ **Levels:** The values that a factor can assume, E.g., the CPU type has three levels: 68000, 8080, or Z80.  
# of disk drives has four levels.  
Also called **treatment**.
- ❑ **Primary Factors:** The factors whose effects need to be quantified.  
E.g., CPU type, memory size only, and number of disk drives.

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## Terminology (Cont)

- ❑ **Secondary Factors:** Factors whose impact need not be quantified.  
E.g., the workloads.
- ❑ **Replication:** Repetition of all or some experiments.
- ❑ **Design:** The number of experiments, the factor level and number of replications for each experiment.  
E.g., Full Factorial Design with 5 replications:  $3 \times 3 \times 4 \times 3 \times 3$  or 324 experiments, each repeated five times.
- ❑ **Experimental Unit:** Any entity that is used for experiments.  
E.g., users. Generally, no interest in comparing the units.
- ❑ **Goal** - minimize the impact of variation among the units.

## Terminology (Cont)

- ❑ **Interaction**  $\Rightarrow$  Effect of one factor depends upon the level of the other.

Table 1: Noninteracting Factors

	$A_1$	$A_2$
$B_1$	3	5
$B_2$	6	8

Table 2: Interacting Factors

	$A_1$	$A_2$
$B_1$	3	5
$B_2$	6	9

## Common Mistakes in Experimentation

- ❑ The variation due to experimental error is ignored.
- ❑ Important parameters are not controlled.
- ❑ Effects of different factors are not isolated
- ❑ Simple one-factor-at-a-time designs are used
- ❑ Interactions are ignored
- ❑ Too many experiments are conducted.  
Better: two phases.

## Types of Experimental Designs

- ❑ **Simple Designs:** Vary one factor at a time

$$\# \text{ of Experiments} = 1 + \sum_{i=1}^k (n_i - 1)$$

- Not statistically efficient.
- Wrong conclusions if the factors have interaction.
- Not recommended.

- ❑ **Full Factorial Design:** All combinations.

$$\# \text{ of Experiments} = \prod_{i=1}^k n_i$$

- Can find the effect of all factors.
- Too much time and money.
- May try  $2^k$  design first.

## Types of Experimental Designs (Cont)

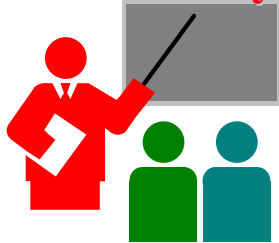
- Fractional Factorial Designs: Less than Full Factorial
  - Save time and expense.
  - Less information.
  - May not get all interactions.
  - Not a problem if negligible interactions

## A Sample Fractional Factorial Design

- Workstation Design:  
(3 CPUs)(3 Memory levels)(3 workloads)(3 ed levels)  
= 81 experiments

Experiment Number	CPU	Memory Level	Workload Type	Educational Level
1	68000	512K	Managerial	High School
2	68000	2M	Scientific	Post-graduate
3	68000	8M	Secretarial	College
4	Z80	512K	Scientific	College
5	Z80	2M	Secretarial	High School
6	Z80	8M	Managerial	Post-graduate
7	8086	512K	Secretarial	Post-graduate
8	8086	2M	Managerial	College
9	8086	8M	Scientific	High School

## Summary



- ❑ Goal of proper experimental design is to get the maximum information with minimum number of experiments
- ❑ Factors, levels, full-factorial designs

## Exercise 16.1

The performance of a system being designed depends upon the following three factors:

- CPU type: 68000, 8086, 80286
- Operating System type: CPM, MS-DOS, UNIX
- Disk drive type: A, B, C
  - a. There is significant interaction among factors.
  - b. There is no interaction among factors.
  - c. The interactions are small compared to main effects.