# 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
"If this doesn't help you don't worry, it's a placebo."

# 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.

# 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** ⇒ 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)

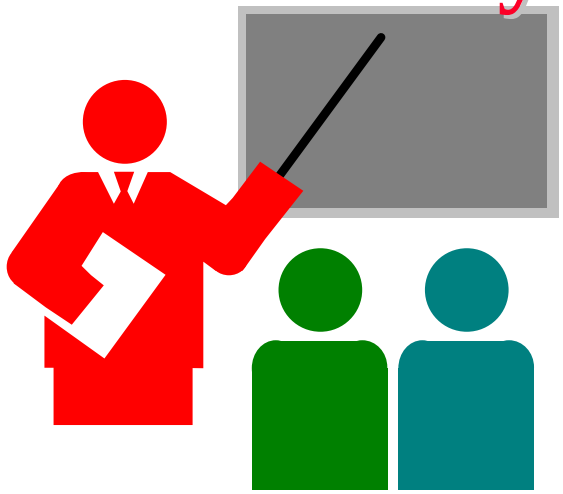
- Fractional Factorial Designs: Less than Full Factorial
  - Save time and expense.
  - Less information.
  - May not get all interactions.
  - Not a problem if negligible interactions

# 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.