Introduction to Experimental Design

- 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

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** $\Rightarrow$ 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)

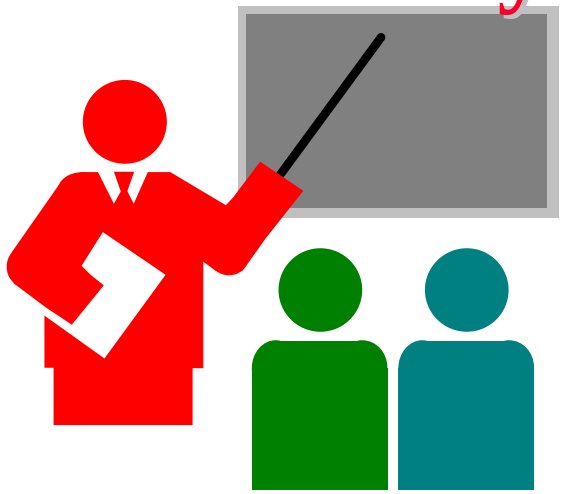
- Fractional Factorial Designs: Less than Full Factorial
  - Save time and expense.
  - Less information.
  - May not get all interactions.
  - Not a problem if negligible interactions

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

How many experiments are required to analyze the performance if:

a. There is significant interaction among factors.

b. There is no interaction among factors.

c. The interactions are small compared to main effects.