MAT 458-Design of Experiments

Introduction

Fuxia Cheng

Outline

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1. Introduction

Statistical studies can be categorized into two main types, observational studies and experimental studies.

- Observational studies are conducted to get an understanding on the prevailing situation.

- Experimental studies are conducted to explore causal relationships.

In an observational study the researchers passively observe the subjects in the population without imposing anything on them. On the other hand in experimental studies treatments are imposed on the subjects and their responses are observed.

Experiments are performed by investigators in all fields of inquiry, usually to discover something about a particular process or system.

We can define an experiment as a test or series of runs in which purposeful changes are made to the input variables of a process or system so that we may observe and identify the reasons for changes that may be observed in the output response.

All experiments are designed experiments, some are poorly designed, some are well-designed

The **Basic Principles of Design of Experiments** are randomization, replication and blocking.

Let's define some of the important terms and concepts in design of experiments.

Treatments are the different procedures we want to compare. These could be different kinds or amounts of fertilizer in agronomy, different long rate structures in marketing, or different temperatures in a reactor vessel in chemical engineering.

Experimental units are the things to which we apply the treatments. These could be plots of land receiving fertilizer, groups of customers receiving different rate structures, or batches of feedstock processing at different temperatures.

Responses are outcomes that we observe after applying a treatment to an experimental unit. That is, the response is what we measure to judge what happened in the experiment; we often have more than one response. Responses for the above examples might be nitrogen content or biomass of corn plants, profit

by customer group, or yield and quality of the product per ton of raw material.

Randomization is the use of a known, understood probabilistic mechanism for the assignment of treatments to units.

Experimental Error is the random variation present in all experimental results. Different experimental units will give different responses to the same treatment, and it is often true that applying the same treatment over and over again to the same unit will result in different responses in different trials. Experimental error does not refer to conducting the wrong experiment or dropping test tubes.

Measurement units (or response units) are the actual objects on which the response is measured. These may differ from the experimental units. For example, consider the effect

of different fertilizers on the nitrogen content of corn plants. Different field plots are the experimental units, but the measurement units might be a subset of the corn plants on the field plot, or a sample of leaves, stalks, and roots from the field plot.

Control has several different uses in design. First, an experiment is controlled because we as experimenters assign treatments to experimental units. Otherwise, we would have an observational study. Second, a control treatment is a standard treatment that is used as a baseline or basis of comparison for the other treatments. This control treatment might be the treatment in common use, or it might be a null treatment (no treatment at all). For example, a study of new pain killing drugs could use a standard pain killer as a control treatment.

Placebo is a null treatment that is used. Placebos are often used with human subjects, because people often respond to any treatment: for example, reduction in headache pain when given a sugar pill.

Factors combine to form treatments. For example, the baking treatment for a cake involves a given time at a given temperature. The treatment is the combination of time and temperature, but we can vary the time and temperature separately. Thus we speak of a time factor and a temperature factor. Individual settings for each factor are called levels of the factor.

Confounding occurs when the effect of one factor or treatment can't be distinguished from that of another factor or treatment. The two factors or treatments are said to be confounded.

Except in very special circumstances, confounding should be avoided.

Consider planting corn variety A in Minnesota and corn variety B in Iowa. In this experiment, we can't distinguish location effects from variety effects (i.e., the variety factor and the location factor are confounded).

Some remarks:

(i) Randomization is the use of a known, understood probabilistic mechanism for the assignment of treatments to units.

Other aspects of an experiment can also be randomized: for example, the order in which units are evaluated for their responses (i.e., running the trials in an experiment in random order).

(ii) Replication: Sample size (improving precision of effect estimation, estimation of error or background noise)

(iii) Blocking is used to deal with nuisance factors.

We compare **treatments** by comparing the responses obtained from the experimental units in the different treatment groups. This could tell us

(i) if there are any differences in responses between the treatments,

(ii) what the estimated sizes of those differences are,

(iii) which treatment has the greatest estimated delay until recurrence, and so on.

An experiment is characterized by the treatments and experimental units to be used, the way treatments are assigned to units, and the responses that are measured.

Experiments help us answer questions. Of course there are also nonexperiment advantages.

This course presumes some knowledge of basic statistical theory and practice. Students are expected to know the essentials of statistical inference like estimation, hypothesis testing and confidence intervals. A basic knowledge of data analysis is presumed. Some linear algebra and calculus is also required.

2. Main topics

(i) Review

(ii) Single Factor Experiments : Checking the model assumptions, Treatment Contrasts, Multiple Comparisons, Randomized Block Designs, Latin Squares Designs, Balanced Incomplete Block Designs.

(iii) Factorial Designs: Fixed, Random, and Mixed Models.

(iv) 2^k Factorial designs: Blocking and Confounding in 2^k Factorial Designs

If time permits, we may also cover the following:

(v) Fractional Factorial Designs and Nested Designs.