Quality Improvement From Disassembly-Reassembly Experiments

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1. Introduction

In this work we consider the problem of detecting a component that impairs quality by systematically inflating the variance in a product that is assembled from "interchangeable components." We discuss the use of "disassembly-reassembly" experiments, a new class of industrial experiments, in which components are swapped among assemblies.

There are two basic types of disassembly-reassembly experiments. In the first type, the experimental components are sampled from a large population. In the second type of experiment, one initially identifies some defective assemblies and some functional assemblies. The experimental components are classified in terms of the quality of the initial assembly.

2. Background

Although there has been almost no statistical research on disassembly-reassembly experiments, the idea goes back almost 70 years. Tippett (1936) described an experiment to solve a quality problem in yarn production using a hyper-graeco-latin square plan. Taguchi (1987) also discussed use of such plans in disassembly-reassembly experiments.

Bothe (1991) and Shainin (1993) have discussed disassembly-reassembly experiments in which the components have been classified according to the initial functional status of the assembly.

3. The Statistical Model

The appropriate model for a disassembly-reassembly experiment depends on the nature of the experiment. When the components have been classified by initial assembly status, standard models for two-level factorial experiments can be applied. When the components are sampled "off the shelf" a mixed linear model is useful. We focus here on an experiment with two components, which we label A and B. Let y denote the performance characteristic and consider the model

$$y_u = \mu + \alpha_{i(u)} + \beta_{j(u)} + \tau_{k(u)} + \varepsilon_u, \qquad u = 1,\ldots m^2 ,$$

where u indexes the experimental assembly, μ is the general mean, $\alpha_1 \ldots ,\alpha_m$, $\beta_1 \ldots ,\beta_m$ and $\tau_1 \ldots ,\tau_m$ are the main effects of A, B and time, respectively, and $\varepsilon_1 \ldots ,\varepsilon_{m^2}$ are error terms. Since component units used in the experiment are sampled from a large population of units, it is natural to consider the factors A and B as *random* effects. Time can be treated either as random or as fixed.

4. Results

For the random effects setting we compared different estimators of the variance components. Maximum likelihood estimators had the lowest mean squared error, despite their negative bias when the variance components are large. Standard ANOVA estimators (both with and without truncation at 0) suffered from much higher variance than the MLE's. Restricted maximum likelihood also resulted in noticeably higher variance than did ML.

We examined power to detect non-zero variance components and also to determine which of two components contributes more variance to product performance. We found that at least a 4 by 4 latin square is needed to have reasonable detection power. In testing for the larger of two components, the power depends not just on the relative size of the components, but also on the size of the error variance. High power is obtained only when the ratio of the two components is large and the ratio of the larger component to the error variance is large.

We have begun a comparison of the relative benefits of each type of experiment. Our results thus far indicate that the two-level experiment, if applicable, is preferable to running a variance component study.

REFERENCES

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RESUME

Les plans d’expériences statistiques sont des outils importants pour obtenir des produits de haute qualité. Nous présentons une nouvelle classe de plans d’expériences statistique qui ont comme objectif l’amélioration de produits qui consistent de components interchangeables.