RESEARCH REPORTS

EXECUTIVE SUMMARIES OF CURRENT STUDIES

EDITED BY MARK S. DASKIN

Industrial engineers have used statistical techniques to monitor processes and improve quality for years. Virtually every industrial engineering student is exposed to techniques such as statistical process control and design of experiments.

In the three papers summarized below, which all appear in the December issue of *IIE Transactions* (Vol. 34, No. 12), we highlight improved techniques for using statistics in process control and experimental design.

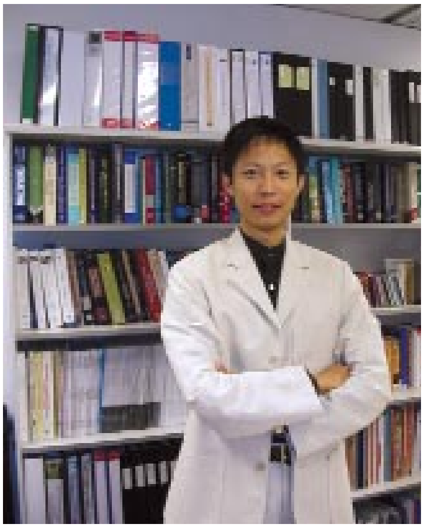
MONITORING PROCESSES

Modern manufacturing processes are often equipped with engineering process control technology that enables automatic or manual feedback adjustments of key process input variables. With a properly designed controller, EPC can be an effective tool for reducing short-term variation in process output variables. For long-term process improvement, however, statistical process control is still recommended for use in conjunction with EPC to detect any out-of-control conditions and remove their root causes. The integration of SPC and EPC has attracted much attention from both academia and industry recently.

In typical EPC environments, where advanced measurement and data collection technology are employed, large volumes of data are routinely available for SPC purposes. Although this opens up many possibilities for integrating SPC and EPC with large potential payoffs in terms of improved process and product quality, there are also a number of challenges.

One primary challenge relates to the statistical difficulties in monitoring a feedback-controlled process via SPC. Conventional SPC methods are inefficient tools for monitoring feedback-controlled processes because they treat the process as a black box and ignore important information such as the structure of the EPC controller and the process models used to design the controller.

In "The Dynamic T2 Chart for Monitoring Feedback-Controlled Processes," Fugee Tsung and Daniel W. Apley develop an SPC scheme (based on a dynamic T2 statistic) that automatically incorporates relevant information related to the dynamics and autocorrelation present in feedback-controlled processes. The paper provides guidelines for designing and implementing the proposed SPC scheme.



Fugee Tsung helped develop an SPC scheme that incorporates information related to the dynamics and autocorrelation in feedback-controlled processes.

A performance analysis indicates that the dynamic T2 monitoring scheme outperforms conventional SPC approaches in EPC environments and is effective in detecting a variety of assignable causes.

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ROBUST ECONOMIC BENEFITS

The economic benefits from the deployment of SPC can be profound. Arko Paper Products Inc. realized a 1,000 percent return on investment in six months after it adopted an SPC program and its scrap rate dropped from 10.1 percent to 1.8 percent. General Motors realized $600,000 in annual cost savings from a single casting operation using an economic design over traditional designs.

Designing a control chart involves making fundamental decisions about the control chart parameters. A common design used for the X-bar chart is to collect a sample of five units from a process after every hour of production, and set the control chart limits at three standard deviations from the mean.

Academic research has been challenging this rule-of-thumb-based approach by introducing more rigorous criteria for selecting the design parameters based on economic factors.

Some academics have advocated the use of economic design of control charts to further improve the economic benefits of SPC. This involves selecting a design that minimizes the quality costs of operating the process in-control and out-of-control, sampling costs, and the cost of investigating control chart signals. However, there has been limited success in industrial implementation of economic designs.

In "Robust Economic Control Chart Design," Kevin Linderman and Adrian S. Choo develop the concept of robust economic designs of control charts whereby multiple economic and process scenarios are considered in control chart design. Using this technique, a central planner can determine a single control chart design that should be effective under a wide variety of settings, thus making economic designs easier to administer. The robust optimization technique for economic control chart design helps planners better understand industrial implementations of economic designs of control charts.

The paper illustrates the effectiveness of this technique through examples and a sensitivity analysis.

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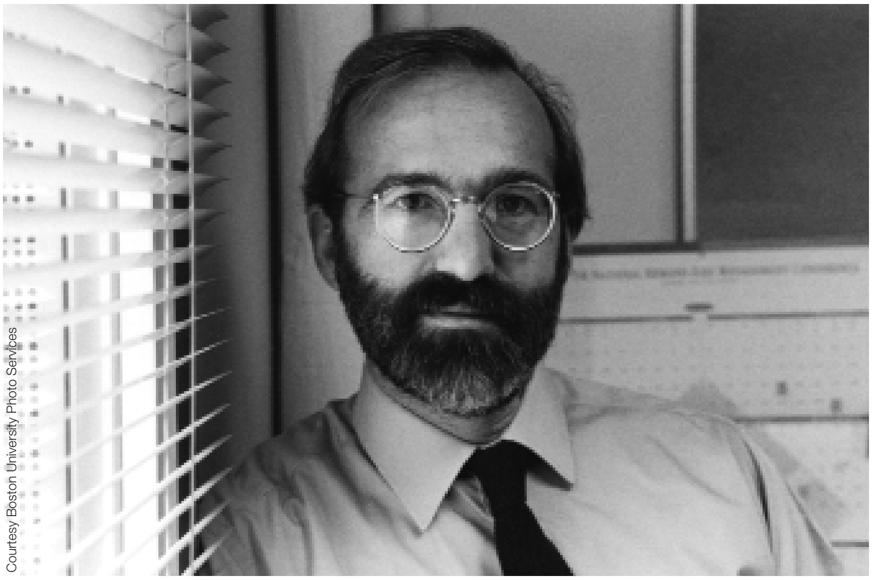
FEWER PROTOTYPES NEEDED


Courtesy Boston University Photo Services

Michael Caramanis' research extends DOE by introducing financial and managerial aspects.

Significant advances in engineering science, modeling, and computer simulation are still short of satisfying all optimal product and process design needs. Many manufacturing, medicine, supply chain, and service system environments require actual construction of multiple product prototypes and experimentation to investigate the performance of a new product, process, or operation design. Delays and high experimentation costs limit the number of affordable experiments.

Design of experiments addresses the judicious choice of a subset of all possible — often infinite — experiments that maximizes the expected obtainable information.

Irad Ben-Gal and Michael Caramanis, in "Sequential DOE via Dynamic Programming," extend DOE results by:

• Introducing the notion of the information state of the design task as a function of information revealed by past experiments.

- Considering explicitly the cost of incremental experimentation and quantifying the value of the additional information that it is expected to provide.
- Describing the dynamics governing the evolution of the information state with future experiments.
- Proposing a sequential approach to DOE that enables decisions about how to design an incremental experiment and whether it is to perform it or stop experimenting altogether.

The proposed sequential DOE is not only more efficient from a statistical point of view, it is financially effective in enhancing the productivity of new product and process development. Its contribution is based on the synthesis of information theory (which enables modeling of the relevant information dynamics) and stochastic dynamic programming (which makes it possible to find the optimal trade-off between current costs and expected future benefits).

The research enhances the existing DOE literature by transcending the consideration of statistical properties and introducing financial and managerial aspects.

The paper illustrates the use of the technique through real-life examples related to supply chains, wafer fabrication material handling systems, and inventory management.

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