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A component-based simulation environment for statistical process control systems analysis

T.A. Spedding[a,*], M. Chandrashekar[b,1,✠]

[a] Medway School of Engineering, University of Greenwich at Medway, Pembroke, Chatham Maritime, ME4 4TB, UK
[b] Systems Design Engineering, University of Waterloo, Waterloo, Ont., Canada N2L 3G1

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Abstract

This paper describes a simulation environment, called Prosim, which permits a user to define components, subsystems, and their interconnections to analyse a statistical process control (SPC) system. The components and systems are defined and analysed interactively. A library of standard SPC objects containing models for the Xbar, range, exponential weighted moving average, *p*-chart and other SPC techniques have been created which help define the control application. The PC-based tool is tested on theoretical, and real data, and is useful for the design and trouble shooting of a manufacturing system. It is also an effective teaching and research tool.
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1. Introduction

This paper explores the use of discrete event simulation for the assessment and design of a quality system. The basic premise is that simulation can be used for exploring and investigating the optimal design of a Statistical Process Control (SPC) system. Prosim, an object oriented continuous time simulation system based on the Graph Theoretic Method (GTM), is utilised as the basis of the simulation modelling technique. This approach has the advantage that each component or subsystem can be separately programmed, turned into an object, and handled independently in time. Other discrete event simulation software can also be used. However, Prosim provides the flexibility required for a unified and systemic approach to the design and modelling of SPC systems.

Three random number generators based on the rectangular, normal and exponential distributions are developed to represent time-based processes found in typical manufacturing systems and in the service industry. Other distributions including non-parametric and empirical distributions can be read directly from data files. Simple out of control mechanisms are explored by implementing an interactive capability which allows the process to go out of control by a combination of assignable causes such shift or drift of the location (mean), or spread (standard deviation). Processes can also exhibit short-term correlation by the implementation of an autoregressive process. Statistical Process Control techniques such as variable control charts (Xbar, Range and exponential weighted moving average (EWMA) charts), attribute charts (*p*-chart), process capability, quality costing, and inspection are implemented. These techniques are represented as components which form a toolbox of SPC procedures that can then be configured in the Prosim environment (using drag and drop facilities) to represent any SPC system. The system can be easily extended to include other statistical process control techniques.

The purpose of this paper is to illustrate and explore the use of a discrete event simulation system to

*Corresponding author. Tel.: +44-1634-883425; fax: +44-1634-883153.
E-mail address: t.a.spedding@gre.ac.uk (T.A. Spedding).
[1] This work was carried out whilst Professor Trevor Spedding and Professor Muthu. Chandrashekar were Associate Professor and Visiting Professor respectively in the School of Mechanical and Production Engineering, Nanyang Technological University, Singapore.
✠ Deceased.

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determine how control charts or other SPC techniques perform in realistic situations. Also, the paper illustrates how a simulation tool can be used as *decision support* so that the analyst can determine which SPC technique is the most appropriate under a set of given conditions. This is illustrated through a series of examples, presented in Section 4, which use operating characteristic curves, average run length charts, response surfaces and scenario analysis of theoretical and actual manufacturing systems, to outline the potential of implementing the approach to assist the quality engineering of a particular system.

1.1. Statistical process control using Prosim

Simulation has been suggested for the assessment of quality characteristics by several authors. (see for example [1–5]).

The underlying advantage of simulation techniques or tools is their capability to model variation. SPC seeks to control and minimise variation through feedback onto the process thus ensuring a continuous improvement system, based on prevention rather than detection.

Several simulation studies have used procedural programming languages such as Fortran and C [4]. Although these languages are extremely capable and flexible programming tools the degree of complexity necessary to develop a comprehensive simulation tool, with time advance mechanisms such as next event scheduling, is a significant limitation. Purpose-built discrete event simulation environments have been developed to investigate the operational characteristics of manufacturing systems. Systems such as Witness™ [6] and Arena™ [7] include excellent graphical interfaces and animation for investigating features such as bottlenecks, length of queues and the rate of utilisation of manufacturing systems. However these systems do not provide an environment flexible enough to easily develop the control charting mechanisms or the out of control characteristics necessary for a detailed simulation of quality control. Discrete Event Simulation packages usually focus on the investigation and analysis of productivity and so it is difficult to isolate SPC issues. Although those packages which include programming capabilities can be programmed to investigate SPC for a specific system they cannot easily be configured for a generic analysis of SPC systems.

Prosim offers a useful compromise. It is a time driven system, which means that events can be naturally programmed in time using a modular programming language. Components, handled as objects, can then be connected together to provide a complete system. Thus components such as random number generation with assignable causes, control charts and feedback operations can be coupled together to provide a complete system of quality operations. Once the code has been developed it can be represented as a single component which can be connected with other components to form a system. Fig. 1 shows an example of a system consisting of a Xbar chart monitoring a machine producing random data with a normal distribution.

Fig. 2 shows a more complex SPC system, which extends the system shown in Fig. 1 to include process capability analysis, costing and written output to a file. Once developed, individual components can be stored in a library to form a toolbox of quality components which, using the drag and drop facility of the graphical interface, can be linked together in different system configurations.

The key features of Prosim that make it flexible are:

(a) independent modelling of each control chart or strategy as a component which is handled by its icon and can be connected with other components to form a system,

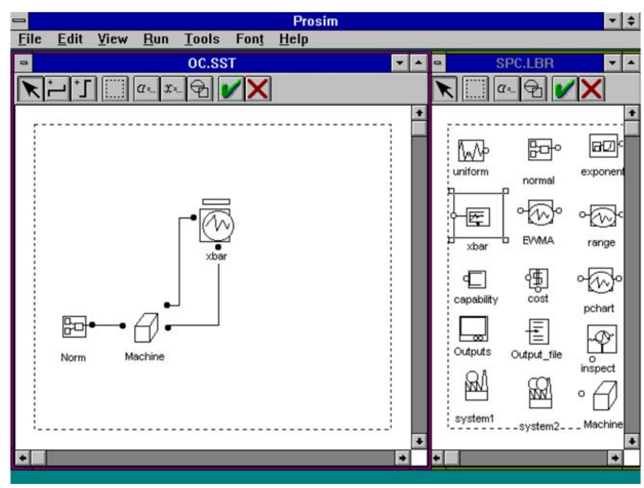

Fig. 1. System including Xbar chart.

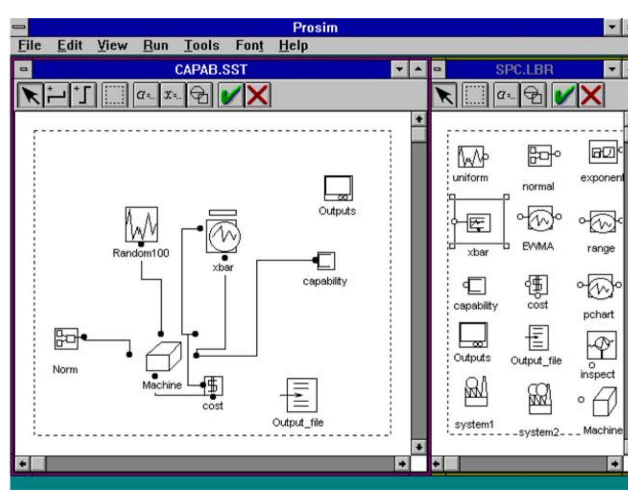

Fig. 2. SPC system with Xbar R chart.

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