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An integrated artificial neural network-computer simulation for optimization of complex tandem queue systems

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Abstract

This paper presents an integrated artificial neural network-computer simulation (ANNSim) for optimization of G/G/K queue systems. The ANNSim is a computer program capable of improving its performance by referring to production constraints, system's limitations and desired targets. It is a goal oriented, flexible and integrated approach and produces the optimum solution by utilizing Multi Layer Perceptron (MLP) neural networks. The properties and modules of the prescribed intelligent ANNSim are: (1) parametric modeling, (2) flexibility module, (3) integrated modeling, (4) knowledge-base module, (5) integrated database and (6) learning module. The integrated ANNSim is applied to 30 distinct tandem G/G/K queue systems. Furthermore, its superiority over conventional simulation approach is shown in two dimensions which are average run time and maximum number of required iterations (scenarios).

Keywords: Computer simulation; Artificial neural network; Tandem queue; Optimization

1. Introduction

Computer simulations are exquisite tools for modeling and analyzing the true performance of evolving production systems. An intelligent simulation environment is a large knowledge integration system, which consist of several symbolic reasoning systems (LISP, PROLOG, etc.) and numerical simulation software. The related concept suggests a framework for integration of numerical simulation, expert system and artificial intelligence techniques. An intelligent computer simulation environment [5] would allow the designers of systems to predict and provide the means to control the relevant disturbances to an acceptable degree of completeness and produce the optimum solution by referring to an integrated database. It would automatically enable us to foresee the behavior of such systems in normal and increased production situations [4]. Furthermore, it should intelligently guide us to a smoother and more efficient performance for production systems. Authors in Refs. [24,38,39] discuss the importance of intelligent simulation modeling and also authors in Refs. [15,29,32,36] to overcome the inflexible and limited issues of traditional simulation techniques propose intelligent knowledge-based modeling.

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The importance of an intelligent approach is more evident by noting the properties and requirements of the manufacturing industry in the future. The challenge is to develop the technology required to achieve a new generation of manufacturing systems. They are not only flexible and integrated, but are capable of adapting themselves to necessary changes [40,41]. Furthermore, the next production frontier is operating factories as learning laboratories [20,23]. By referring to the desired target, an intelligent simulation environment could aid us overcome the evolving requirements of the factory of the future.

In this paper, an intelligent modeling environment is proposed which has flexible, integrated, and knowledge-based structure capable of learning and self-correction. It is goal-oriented and searches for the best solutions by referring to desired target. Moreover, key characters of simulation behavior have been trained and used for system classification. Since most processes of the real world are in disorder and do not have plausible models, the neural networks are used to forecast system performance with respect to input conditions. It is the objective of this paper to describe an intelligent neural network-based simulation environment for optimization of the performance of queuing systems. An intelligent simulation environment is proposed by integration of: (1) an integrated data base and modeling, (2) goal-oriented behavior and (3) parametric and flexible structures discussed in this paper. The prescribed framework is discussed for 30 distinct tandem G/G/K queue systems.

The remainder of the paper is organized as follows. In Section 2, a literature survey on the application of simulation and intelligent simulation for manufacturing in general and queuing systems in particular is presented. In Section 3, the intelligent artificial neural network-computer simulation (ANNSim) environment and its features are discussed. In Section 4, the methodology of artificial neural networks is presented. Section 5 elaborates on the structure of ANNSim environment for G/G/K queuing systems. In Section 6, to examine the robustness and usability of the proposed algorithm, a prototype of the intelligent simulation is created and applied for performance optimization of a G/G/K queue. This paper ends with conclusions and further research directions.

2. Literature review

In the literature, successful uses of simulation for performance evaluation/optimization of complex networks of queues and manufacturing systems have been reported. Pardo and De La Fuente [34] have used simulation to obtain optimum selection of the service rate for a finite input source fuzzy queuing system. Canonaco et al. [13] have used simulation to propose a queuing network model to manage berth crane operations. Manitz [25] has proposed the approach for the production process on multi-stage assembly lines. The two-station subsystems are analyzed by G/G/1/N stopped-arrival queuing models. A discrete-event digital simulation model is developed in Ref. [16] to calculate performance measures of M/G/C/C state-dependent queuing networks applicable to pedestrian planning evacuation problems in buildings. Andriansyah et al. [2] use simulation to validate and assess the quality of optimal solutions generated by their new modeling for Open zero-buffer multi-server general queuing networks applicable in process industry. Authors in Ref. [17] use simulation to estimate the performance measures of a finite state-dependent queuing networks applicable for congestion modeling in mobile communication systems.

In recent years, artificial intelligence has been integrated in manufacturing simulation and modeling. Intelligent simulation environments are also proposed for flexible manufacturing systems, information systems, process plants, just-in-time, aerospace manufacturing systems and supply chain management [1,12,26,42]. A recent study [31] developed an intelligent simulation environment which uses reactive scheduling scenarios in a specific flexible manufacturing system (FMS) configuration. Some other intelligent applications of simulation could be found in Refs. [7,6,43].

Artificial neural network is one of intelligent techniques introduced in 1982 [19]. Compilation of simulation by neural network speeds up the simulation process and help optimization process, see for example [37]. One of such advances [22] proposed an object oriented model for integration of simulation and artificial intelligent techniques for special manufacturing processes. Moreover, knowledge base and artificial intelligence have been incorporated into simulation software. Integration of simulation and the neural network reduces communication delays and improves responsiveness of the system to changes in production and new scheduling need. ANN has been used in combination with simulation in different applications. Martens and Puwels [27] have used neural network for validation of simulation models. Nazarov and Apanasavich [30] proposed a method to recognize suitable parameters for simulation and ANN. Chambers and Mount-Campbell [14] developed an ANN meta-model of system components. The ANN is trained via simulation to act as a single queuing node which accepts input data on inter-arrival and service distributions.