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Simulation modeling in heterogeneous distributed computing environments to support decisions making in warehouse logistics

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Abstract

We address an important problem of automation in simulation modeling of logistics warehouses. An effective solution for such a large-scale problem is difficult to obtain without high-performance computing. To this end, we propose a new approach for adjusting management system parameters of the warehouse in its production use. It is based on the integration of conceptual, wireframe, and service-oriented programming used to develop parameter sweep applications and data analysis in simulation modeling in heterogeneous distributed computing environments. We design a toolkit to support modeling of warehouse logistics. Using this toolkit, we develop a parameter sweep application and solve three optimization tasks for adjusting parameters of a warehouse management system. The practical experiments are focused on the refrigerated warehouse. The developed applications demonstrate high efficiency and scalability capabilities to optimize nine criteria to cope with different production demands.

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Keywords: simulation modeling; queue systems; toolkit; distributed computing; parameter sweep applications

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1. Introduction

A study of complex technical and economic systems at different stages of their design and functioning is one of the important problems in simulation modeling. Often, effective modeling of the systems for manufacturing, material handling, transportation, storing, communication, information processing and other more processes are based on using a queuing systems theory.

An important class of queuing systems are Logistics Warehouses (LWs). These systems are oriented to the management of large-capacity cargo traffic, distribution of goods, etc. The functioning of modern LWs is associated with complex operation processes of the aforementioned queuing systems, taking into account their important role in the economic sphere. In this regard, the most important problems in warehouse management are functional and organizational structure analysis and optimization. To a certain extent, these problems can be solved by Warehouse Management Systems (WMS) that provide automation of a business process and support for decision making [1].

The trends of modern LWs include improvement of technologies, communication systems, expansion of a set of warehouse and logistic operations, increasing operational complexity, designing efficient logistic decisions, optimization tools, etc. Simulation modeling is one of the most effective approaches for LWs' functioning analysis [2]. It allows observing the behavior of LWs over time to identify parameters that influence their warehousing processes, and predict their behavior in the future.

A simulation modeling methodology gives users the ability to examine operational schemes and their parameters, and test effects of these alternatives without experimenting in a real environment, which is often too costly or impossible. It simplifies the optimization of control parameters for LWs operational schemes [3]. A process of the LW study implies a development of simulation program of warehouse operations, and its execution with a parameter sweep. In the parameter sweep, users adjust the values of parameters by sweeping their values in defined ranges. These experiments provide a low-cost method to determine the optimal parameters for operations.

The efficiency of results directly depends on the problem-oriented knowledge usage [4]. For example, Felice and Petrillo [5] present a successful application of simulation modeling based on problem-oriented knowledge in the decision-making process for the manufacturing system. Gwynne [6] discusses how to operate an efficient and cost-effective warehouse. Unfortunately, often, they do not take into account unpredictable factors and production uncertainties [7, 8], and do not have tools for solving various unexpected problems of warehouse management.

Efficient management includes:

- Modeling logistic operations to determine their time and cost parameters, taking into account service delays and risks associated with a human factor;
- Developing equipment maintenance plans considering random failures;
- Analysis of customer service levels and prediction of the possible financial results for different periods.

High-performance computing (HPC) seems to be an essential part of large-scale mathematical modeling. It provides significant computational speedup based on the parallel processes execution. The scale in number of computational elements and complexity of systems is increasing dramatically. Applications also need to scale upwards to address this challenge by improving performance. Problem-solving time should decrease with increase in a number of the nodes. Thus, it is essential to design special tools for development of simulation programs that are parallel and scalable.

Law [9] notes that the simulation program design, which adequately reflects the studied system, is a non-trivial problem and requires high mathematical and programming skills, especially, when parallel and distributed programs are developed [10]. Thus, to automate this process, there is a need for high-level tools that reveal the potential of HPC and support a complex technological process from the problem formulation to model creation.

An analysis of recent publications in the field of simulation modeling of queue systems shows that managers may choose from available simulation tools that differ in the accuracy of real-world representation and performance [11-14]. However, many tools do not use HPC power, and do not consider all details of subject domains [15]. Services and their delivery for users are also important components for interfaces of modern simulation tools [16].