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An integrated modeling mechanism for optimizing the simulation model of the construction operation

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Abstract

A planner may use the discrete-event simulation to analyze and design the construction operation process that optimizes the overall performance of a construction system. Normally, the basic elements used in construction operation process simulation system, such as CYCLONE (CYCLic Operation NEtworks), are "activity" and "queue." Activity is used to model the task which consumes resources and takes time to perform. Queue acts as a storage location for resources entering an idle state. In the simulation system, queues have to be created according to the ways of assigning resources to activities. Conventionally, planner defines queues according to his/her judgment by determining which and what amount of resources should be allocated to which activity. Consequently, various modeling schemes have to be examined to obtain the best simulation model. However, such a process of creating queues and activities is time consuming and requires iterations. This paper introduces a Genetic Algorithms (GA)-based modeling mechanism to automate the process of selecting the optimal modeling scheme. Case study shows that this new modeling mechanism along with the implemented computer program not only can ease the process of developing the optimal resource combination but also improve the system performance of the simulation model.

Keywords: GA; Simulation; Resource assignment modeling

1. Background

Discrete-event simulation has been used to assist construction engineers in analyzing and designing construction operation processes for years. One of the advantages to utilize simulation in designing construction processes is that planners may examine various schemes of the simulation model to better understand how resources influence the overall performance of a construction system so as to select a better resource assignment. Usually, there are two ways to conduct the above experiment. One is to establish a single model and then conduct simulations by examining different resource combinations to find out which resource combination optimizes the system performance. Another, a more complicated one, is to test each possible scheme of model that involves in building various simulation components within the simulation model and then test the system performance through running all resource combinations in each modeling scheme. The former only has to deal with the available resource combinations; however, the latter one has to deal with the modeling schemes and the resource combinations.

The traditional way to determine the optimal resource combination of a single simulation model is to exhaustively examine all resource combinations. Riggs [1] proposed a computer-based program called sensitivity analysis for facilitating such enumeration. However, if possible resource combinations increase explosively, sensitivity analysis could be extremely time consuming. As a result, AbouRizk and Shi [2] proposed a heuristic algorithm (HA) which efficiently locates the most appropriate resource allocation of the simulation system. Whereas, the solution of their heuristic approach is usually the local optimum and the performance of such an approach is problem-dependent.

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Therefore, Cheng and Feng [3] integrated Genetic Algorithms (GA) and simulation to efficiently find the optimal resource combinations in terms of different objectives, such as minimizing the unit cost or maximizing the productivity rate of the simulation model. Similarly, Hegazy and Kassab [4] used GA simulation technique for resource optimization in construction planning. Furthermore, Cheng et al. [5] combined HA and GA to improve the efficiency of only using GA for locating the optimal resource combination. Though several approaches were proposed to find the optimal resource combination of a single simulation model, determining the optimal scheme of a simulation model which involves building various simulation components within the simulation model and finding the optimal resource combination have not been well explored.

This paper proposes a modeling mechanism that uses Genetic Algorithms (GA) as the optimization engine to automate the process of selecting the optimal modeling scheme of a simulation model. In addition, a computer program that integrates the proposed with CYCLONE (CYCLic Operation NEtworks) simulation methodology is also presented in this paper.

2. Problem statement

Generally, the basic elements used in the simulation system, such as CYCLONE (CYCLic Operation NEtworks), are "activity" and "queue." Activity is used to model the task which consumes resources and takes time to perform. Queue acts as a storage location for resources entering an idle state. In the simulation system, queues have to be created according to the ways of assigning resources to activities. Conventionally, planner defines queues according to his/her judgment by determining which and what amount of resources should be allocated to which activity. For instance, suppose there are three activities (say 1, 2, and 3) which consume resource A. Intuitively, the construction engineers may distribute resource A to those activities in various ways. All A can be modeled in one queue indicating that the activities share the same pool of A. A may also be distributed to each activity without sharing, and then three queues have to be created in the model. Moreover, any two activities may share the same pool of A and one activity possesses its own A, as a result, two queues need to be drawn. One queue stores the resources shared by two activities and another one provides resource solitarily used by another activity. However, since any two activities sharing the same pool of resource may have different impact on the system performance, three different resource distribution scenarios have to be generated (i.e., activities 1 and 2, 2 and 3, or 1 and 3 can be modeled for sharing the same pool of A, respectively) to see how those modeling schemes can influence the simulation model. As it can be expected, if the modeled simulation system is complex, the task of verifying the performance of all possible modeling schemes and finding the optimal resource combination could be extremely time consuming. Therefore, there is a need to develop an efficient and effective modeling mechanism to automate the process of selecting the optimal modeling scheme of a simulation model.

3. CYCLONE methodology and COST program

CYCLONE methodology developed by Halpin [6] is the first simulation system particularly designed to analyze and plan the construction operation process. Table 1 presents the basic modeling elements used in CYCLONE and reader may refer to [7] for the details. Since CYCLONE is widely

Table 1
Modeling elements used in CYCLONE

Name	Symbol	Function
Normal activity		Units arriving at Normal will be processed right away without delaying.
Combination (COMBI) activity		Units arriving at COMBI will be processed if units are available in all preceding Queue node.
Queue node		Queue provides position that allows units are delayed pending COMBI activities.
Consolidate function node		Consolidate function node performs the consolidate marking.
Counter		Counter measures the modeled system's production rate.
Arcs		Arcs show the logic that units flow from element to element.