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Discrete event simulation model reduction: A causal approach

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Abstract

Discrete event simulation is an important system analysis technique. But for today's demand for speed, the time to complete a simulation study is considered to be long, even with current developments in hardware and simulation software. In this scenario, simplification methods for simulation models could play a key role. This paper proposes a technique for reducing the complexity of a discrete event simulation model at the conceptual phase of simulation modeling that can be fully automatized through a computer program. We applied this technique on some problems which demonstrate the feasibility of this approach.

Keywords: Discrete event simulation; Model reduction; Simulation model simplification

1. Introduction

Current simulation studies are being performed by means of more complex models. This is allowed by the development of powerful computer hardware and software (a more detailed discussion of some of these factors is provided in [1]). Complex and huge simulation models forces modelers to face problems they were not used to, referred by Page et al. [2] as "Problems of Scale".

Despite of the growth of more complex models, several authors reinforced the importance of simpler simulation models [3–9]. Salt [10] asserts that "simplification is the essence of simulation" and Pidd [11] is conclusive in his declaration: "Complicated models have no divine right of acceptance".

Unfortunately according to Brooks and Tobias [12,13] there is a scarcity of simulation research in the field of simplification of simulation models. These authors also mentioned that the majority of work in this field does not constitute a general methodology to simplify a given simulation model.

The aim of this paper is to propose a technique for reducing the complexity of simulation model at the conceptual phase of simulation i.e. when the results of simulation runs are yet known.

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This paper is organized as follows: Section 2 makes a brief review in literature regarding model reduction or simplification. Section 3 defines the reduction problem; Section 4 gives a brief explanation on the chosen model representation technique for the reduction process. In Section 5, we explain how the reduction algorithm works, and in Section 6, we present a simple application example while in Section 7 a more complex example is shown. Finally, Section 8 concludes this paper, adding directions for future work.

2. Literature review

"Simplicity" is an issue extensively studied in several fields, being philosophically discussed in [14] in his famous book "The Myth of Simplicity". It took different forms in Science and Engineering: examples of reduction processes in mass-spring systems and in control theory are found respectively at [15,16].

In the area of discrete event simulation, as mentioned before, there is a scarcity of research. In fact, according to Sevinc [17]: "No complete theories of model abstraction exist, nor does any sufficiently general procedure". The field, with only less than half a dozen published articles, is wide open inviting the attention of simulation methodologists".

A consensual name for this subject has yet to be defined. This work adopted the expression "Model Reduction", but in literature it can be also founded under names as "Simulation Model Abstraction" [17–19] and "Simulation Model Simplification" [12,13].

According to Brooks and Tobias [13], a simplification method can be divided into three categories: coding tricks, simplifications that preserve the output of interest and simplification that preserve the output approximately. For the sake of quick referencing, we will name here these kinds of simplification as type I reduction, type II reduction and type III reduction.

One of the firsts attempts to find a reduction method is attributed to Zeigler [20]. Others also propose some methods [4,5,8,21]. The majority of these general rules could be classified into three categories of simplification [9]: Omission, Aggregation and Substitution. Courtois [22] discussed some matters related to time scale, which can lead to possible decompositions of simulation models. Sevinc and Foo [23] and Sevinc [17] have developed a simulation model reduction procedure, based on the DEVS developed by Zeigler [20,24]. However, there was a need to run the model to obtain a result for the reduction procedure. McGraw and MacDonald [19] proposed also some techniques for reducing the complexity for engineering and engagement level simulations while Brooks and Tobias [13] proposed them in the realm of Manufacturing Simulation. Nevertheless again these constitutes only some "rules of thumb" for reducing the complexity of simulation models.

Another technique considered by some authors as reduction process of simulation model is metamodeling. In this case, a mathematical model of a simulation model is created in order to imitate its input–output behavior. Barton [25] does a metamodel review in literature and Caughlin [26] presents new procedures for the generation of metamodels. Some new procedures utilize neural network technology to do the input–output correlation [27]. Metamodeling could be considered as reduction type III since the generated input–output behavior is an approximation of the original one.

It is also possible to achieve reduction by changing a modeling paradigm. Yan and Gong [28] proposed to model high-speed networks using discrete event simulation in conjunction with fluid simulation (a technique they called "time-driven fluid simulation"). This approach resulted in "good enough" approximations in feasible computational times in specific cases, which would be impractical if only discrete event simulation was used. Nance et al. [29] demonstrate also that a methodology can induce redundancy, and propose methods for eliminating some redundancies on ACIG graph derived from Condition Specification (see Section 4 and Appendix A.2 for a small review on CS). The ACIG graph is a mapping of attributes of the condition specification, and [29] show that by cutting unnecessary edges of the ACIG graph and executing a simulation directly from it using a direct execution algorithm, it is possible to reduce the computational execution time up to three times in some test problems.

An additional related issue to model reduction relies on how one can measure complexity of the simulation models by an objective measure. Even with an agreed measure, the definition of complexity has no unanimity, as pointed out by Brooks and Tobias [12]. According to Brooks and Tobias [13], however, it is possible to consider complexity of a simulation model by analyzing the amount of components of a model and the amount of connections.