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# A METHOD FOR PARALLEL SIMULATION OF CLASSIC DEVS MODELS WITH COUPLING RELATION GRAPH

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## ABSTRACT

Many DEVS extensions have been suggested for parallel simulation execution, but their modeling semantics often became much complex leading to a difficulty in model development. This paper proposes a new simulation method for parallel simulation execution of classic DEVS models. Specifically, the proposed method identifies events to be processed concurrently using a graph representing the whole event paths, and an event-oriented scheduling is applied to managing the parallel simulation execution.

## 1 INTRODUCTION

Discrete Event System Specification (DEVS) is one of the most widely used simulation methods in various domain problems (Zeigler et al. 2000). One reason of this success comes from its sound and succinct modeling semantics, such as its hierarchical and modular modeling, and this trait helps modelers to reflect their domain knowledges in a simple but explicit manner. On the other hand, classic DEVS simulation often brings up longer simulation execution time, which promotes its parallel extensions. Parallel DEVS (Chow and Zeigler 1994) is an example of such extensions, and it so far has applied to a number of DEVS-based simulation frameworks. However, those works added new concepts (i.e., bag events and confluent function in parallel DEVS) to classic DEVS for parallel simulation execution, which made the easy model development being diminished. This paper proposes a new method for simulating classic DEVS models in parallel; the proposed method adopts an event-level scheduling where multiple events to be processed concurrently are identified and processed in a multi-core environment. The case study partly shows that the proposed method secured both the simulation speedup and the easy model development.

## 2 PARALLEL SIMULATION OF CLASSIC DEVS MODELS

This paper proposes an algorithm for simulating classic DEVS models in parallel. In particular, the proposed method revised the DEVS abstract simulation algorithm in the point of handling the events that are available to be processed simultaneously. We defined these events as the concurrent events at time $t$. In the classic DEVS, atomic models generate or consume events at time $t$, and they are sequentially simulated by DEVS semantics. The proposed method, on the other hand, processes those events in parallel, and which starts with how to identify those events using DEVS specifications.

To do this, we adopted a Coupling Relation Graph (CRG) that represents all event paths specified in a DEVS model (Bae et al. 2016). CRG was originally proposed to reduce simulation execution time in dynamic structure models. Based on the event path information, the proposed method can check whether which events can be concurrently processed or not. For example, we assume that there is a DEVS model containing three atomic models, such as $A$, $B$, and $C$. Output events $e1$ of model $A$ and $e2$ are connected

with an input event $e3$ of model $C$, and an output event $e4$ of model $C$ is connected with an input event $e5$ of model $A$. The DEVS specifications represent such connection information, and CRG representing those connections in a graph structure could help to query the paths of the generated events. From these event paths, for example, we can know that by the DEVS semantics, $e1$ and $e4$ should not be concurrently handled, but $e1$ and $e2$ can do. Also, the event-oriented concept, where events to be handled are stacked into an queue, is employed into the proposed method and manages parallel computing in a multi-core environment.

The multi-server queuing model consisting of generator, buffer, processor, and transducer is used for the efficiency evaluation. Figure 1 shows the average elapsed simulation execution time from various experimental case. The result shows that the proposed method significantly reduces simulation execution time. Also, although it may belong to the model structure, as the number of Buffer-Processor (BP) models is increased, the execution time becomes shorter.

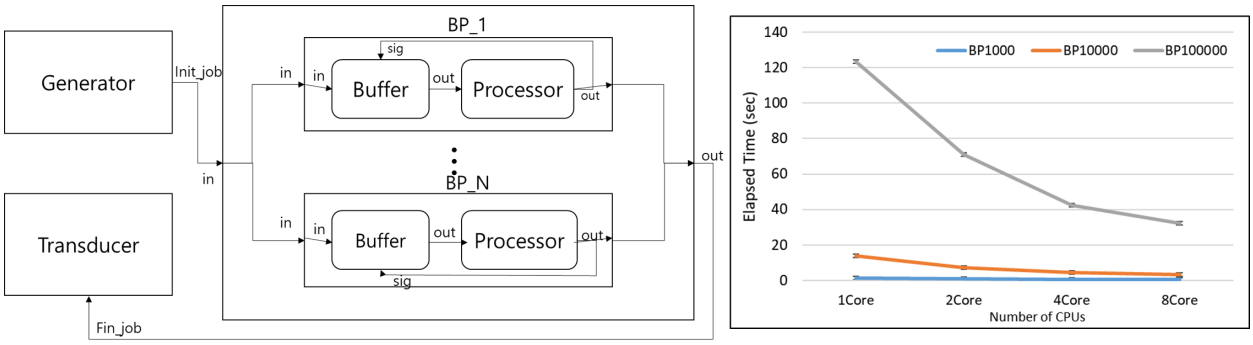


Figure 1: (left) structure of multi-sever queuing model (N servers); (right) elapsed simulation execution time with varying the number of BPs and cores.

## 3 CONCLUSION AND FURTHER WORKS

This paper proposes a simulation method for the parallel simulation of classic DEVS models. The efficiency of the propose method partly was shown through the case study; nonetheless, we also consider there requires deeper analyses using more complex models. Also, extending it for agent-based modeling and simulation is our another future work.

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