Method for Improving the Efficiency of Simulation of ICT and BP Systems by Using Fast and Detailed Models

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Abstract: This paper describes how the fast and detailed modelling and simulation methods can be used to increase the efficiency of simulation of interconnected ICT (Information and Communication Technology) and BP (Business Process) systems. The *method of cooperating models* using detailed, fast and contracted fast models to model the functioning of ICT and BP is presented. A new approach, the diversified assignment method is described for the selection of the appropriate, efficient modelling and simulation method taking into account the criticality of the systems and the phase of simulation (preliminary and detailed). A system of cooperation of fast and detailed models is introduced for the preliminary and detailed phases of simulation and for the basic ICT-BP model configurations (ICT-BP focus).

Keywords: discrete-event simulation, fast models, detailed models, information and communication systems, business process systems, efficiency of simulation, preliminary modelling

1. Introduction

The efficiency of simulation may be influenced by many factors including *methodological factors* too.

The simulation projects of Information and Communication Technology (ICT) systems and related Business Process (BP) systems are usually treated as separate projects but the *common* analysis of these systems may have benefits because these systems may have significant influence on each other in an *organisation*. This is why an increasing need for the common analysis has been occurred.

In the common analysis of ICT and BP systems one may easily be faced with the case of modelling and simulation of large and complex systems where the increase of the efficiency of simulation is necessary. The efficiency of simulation may be increased by using a *combination* of *fast*, *approximate and detailed methods* together.

For this purpose, we need to have methods appropriate for both types of systems: we need to have models of ICT and BP systems that can *interact* with each other just as these systems interact in the real world.

Simulation is a process of developing simulation model of the system of interest and performing experiments with the model in order to reach the defined goals.

The *process of simulation* lasts from the identification and investigation of the need for developing a simulation model of a system of interest to providing support to implement the results of the simulation.

In an organisational environment, we may look at the process of simulation performed as a *project process*, initiated to reach pre-defined goals, within time and cost limits and with the required quality, and using the assigned resources.

In order to improve the *efficiency of simulation,* we should focus not only on the question of *direct efficiency* – which can be measured by the proportion of the required outputs and the resources used to produce the output. It seems to be fruitful to apply Checkland's approach *to efficiency of activity systems* [1], [2] that is to addresses the problem of *efficiency* together with the examination of questions of *efficacy* and *effectiveness*.

Using Checkland's approach, the concept of the *systems approach of efficiency of simulation* may be defined [22]. The *systems approach of efficiency* – examining the criteria of *methodological efficacy, efficiency and effectiveness and gap efficiency* – takes into account of a wider environment and a longer time frame both for the simulation process and for its organisational environment.

Discrete-Event Simulation (DES) can be used for detailed and accurate analysis and performance evaluation of ICT systems [6], [16] and BP systems [26], [8]. Simulation models of ICT systems (*DES-IT* for short in this paper) and simulation models of BP systems (*DES-P* for short in this paper) have similarities but their semantics are different.

The fast and approximate performance estimation can be very useful in the early stage of simulation projects.

The *Traffic-Flow Analysis (TFA)* [9], [10], [13], [21], which is a combination of simulation and statistical approaches, was proposed for the *fast modelling* and *preliminary* performance estimation of ICT systems.

The *Entity Flow-Phase Analysis (EFA)* [11], [15], which was derived from TFA, is a method for the fast modelling and preliminary investigation of BP systems.

Contracted TFA and EFA models, as simplified TFA and EFA models, were proposed to be used in the phase of preliminary examination of ICT and BP systems [14], [20].

This paper describes the method *of the cooperating models* according to which the efficiency of simulation can be increased comparing to other approaches (e.g. [26]) by using *detailed* models (with high resolution) – which are resource, time and computing power consuming – only for that phase of simulation and for that part of the systems when and where they are beneficial and using fast, approximate models otherwise.

The method of cooperating models consists of methods appropriate for the combined use of fast and detailed ICT and BP models in the phases of *preliminary* and *detailed* modelling and simulation. In the paper, both components of – the *diversified assignment* *method* and the *methods of cooperation of models* – are described. The *diversified assignment method* supports the selection of the appropriate modelling methods by evaluating the *criticality* of systems to be modelled and by taking into account the appropriate *resolution* of models.

Traditional *parallel simulation* methods (Parallel Discrete Event Simulation, PDES) (e.g., conservative, optimistic [4], [5]) can rarely provide an attractive speed-up or cannot be scaled up well [7], [28]. In the simulation of organisational ICT and BP systems, *the method of cooperating models,* the combined application of fast (TFA, EFA, contracted TFA and EFA) and detailed (DES-IT, DES-P) methods may give the *required improvement* [12], [20].

The remainder of this paper is organised as follows. Section 2 describes the basic features of detailed and fast methods of simulation of ICT and BP systems. Section 3 deals with the diversified assignment method. Section 4 describes the requirements of the cooperation of models. Section 5 focuses on the definition of the basic configurations of modelling and simulation. Section 6 summarises the work.

2. Detailed and Fast Methods

First, the most important features of the detailed, fast and fast contracted modelling methods are summarised.

2.1. Detailed modelling of ICT systems: DES-IT

As for the detailed modelling of ICT systems, we usually model some servers (database, web, etc.) and the communication networks. We model the networks as a graph of nodes and lines. The load of the systems we describe by applications that use some services. They cause load for the servers by their requests and for the network by communication: sending and receiving packets to/from the servers (or sometimes to/from each other). Discrete event simulation can be used to make experiments with this type of models. We use the abbreviation DES-IT, to distinguish it from the simulation model of the BP systems.

2.2. Detailed modelling of BP systems: DES-P

As for BP systems, we use the definitions we have given in [11]:

"Business processes are related to enterprises and they define the way in which the goals of the enterprise are achieved.

A Business Process is a set of Enterprise Activities linked together to form a process with one or more kinds of input to produce outputs."

We model a BP system by a graph built up from activities (as nodes) and links (as edges) between them. The load is modelled by entity generators, which generate entities of different types according to given probability distributions. The entities travel through the network according to the routing decisions of the activities. The activities use resources of given types with limited capacities. The activities forward the entities after some processing delay that depends on the type of the entity, the type of the activity and the availability of the limited resources.

The simulation model we use for the detailed discrete-event simulation of a BP system is named DES-P.

2.3. Fast Modelling of ICT systems: TFA

The Traffic-Flow Analysis (TFA) is a simulation-like method for the fast performance analysis of communication systems. TFA uses statistics to model the networking load of applications.

In the *first part*, the method distributes the traffic (the statistics) in the network, using routing rules and *routing units*.

In the *second part*, the influences of the finite line and switching-node capacities are calculated.

The important features of TFA:

- The results are approximate but the absence or the place of *bottlenecks* is shown by the method.
- The execution time of TFA is expected to be significantly less than the execution time of the detailed simulation of the system.
- TFA describes the steady state behaviour of the network.

2.4. Fast Modelling of BP systems: EFA

The Entity Flow-phase Analysis has been derived from TFA. This derivation is based on the formal similarity of the DES-IT and DES-P models. EFA uses the same two phase method as TFA, only the interpretation of the model elements is different. The statistics represent entities (not messages) and the interpretation of the routing is also different. While the packets of a network usually do not multiply, the entities may fork (and the descendants must meet somewhere) or split (and the descendants live their own life separately); see more details in the aforementioned paper.

2.5. Contracted TFA and EFA models

If a set of systems is modelled by contracted TFA (or EFA) models then they behave as one TFA (or EFA) model, using one *routing unit* for the whole set of systems. This approach could result in further increase of the speed of examination.

3. The diversified assignment method

Let us examine the *method assignment* problem from the point of view of *systems approach efficiency*. Using detailed modelling in every phase and to every part of the systems of interest to be modelled can be *inefficient and ineffective* : detailed models (with *too high resolution*) in *preliminary modelling* or in modelling of *non-critical systems* may lead to the waste of modelling and computing efforts and may require more time for the project. An improvement of efficiency of simulation may be reached by using detailed methods for *critical* systems and fast methods for non-critical systems. Furthermore, this way, *the efforts (more detailed model, larger amount of computing) can be directed to critical systems*.

Now, let us *formulate* the *rules* of the *diversified assignment method.*

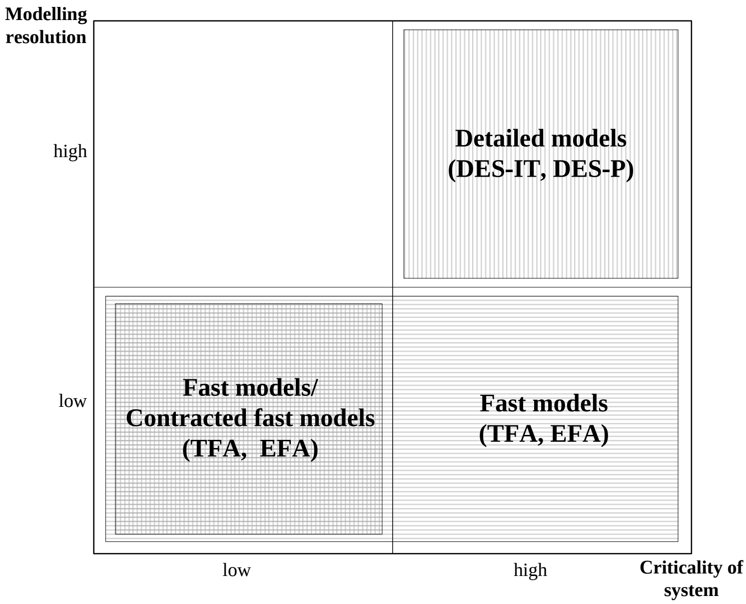

Figure 1. The Concept of the Diversified Assignment Method

For *preliminary modelling*, it is beneficial to use fast methods for the whole system, that is for systems or parts of systems with low and high criticality too: in case of *high criticality* (proto-criticality), *fast models* should be assigned – *TFA* and *EFA* with necessary but low *structural resolution* and with necessary but low *time resolution* (that is with a necessary but low number of routing units – and in case of *low criticality* (proto-non-criticality), *contracted* (simplified) *fast models* (*contracted TFA* and *contracted EFA*) should be used. (In preliminary modelling, the *principle of parsimony*[1] – which improves *methodological effectiveness* – should be taken into account too.) (In Figure 1, the area filled with horizontal lines shows the preliminary modelling.)

Of course, in *detailed modelling* phase, for systems or parts of systems with *high criticality* , (critical systems) d*etailed models* (*DES-IT, DES-P*) proposed to be used and for the systems or parts of systems with low criticality (non critical system and systems of environment) it is enough to use *fast models* (*TFA, EFA*). (In Figure 1, the area filled with vertical lines shows the detailed modelling.)

The criterion of efficiency leads to the assignment and application of different models together: *a set of cooperating models could be the efficient assignment*.

[1]As for preliminary modelling, it is the best to apply the *principle of parsimony* [27]; i.e. that the final simulation model should be built in incremental steps starting from a non-complicated model.

The concept of the *diversified assignment method* is summarised in Figure 1. (The empty area in Figure 1 illustrates that for systems (or for parts of the systems) with low criticality it is not appropriate to use models with high resolution.)

4. Features of cooperation of models

In the following, the *basic configurations* of the assignment and their model-communications requirements will be examined in case of detailed/preliminary modelling of ICT and connected BP systems.

4.1. System-model matrix of cooperation for detailed modelling

In the system-model matrix for *detailed modelling* there are shown four types of models: DES-IT and DES-P models for modelling the critical ICT and BP systems (or critical parts of systems) respectively, and we have TFA and EFA models for modelling the non-critical ICT and BP systems (or non-critical parts of systems) (Figure 2). The cooperation between systems (denoted by numbers 1-6) is also demonstrated in Figure 2.

In the case of the analysis of interconnected ICT and BP systems, we may have three *basic configurations*:

1. Figure 2(a) – Both ICT and BP systems are in the focus of the analysis. In this case the ICT system is modelled by a DES-IT model and the BP system by a DES-P model. Cooperating DES-IT and DES-P models have to use change of interpretations in their communication (denoted by number 2). If the ICT system has a non-critical part a TFA model can be used for modelling it. Between cooperating DES-IT and TFA models, there is a change of representations in communication (denoted by number 1). In the case of BP systems, the EFA model is used to model the non-critical part and there is also a change of representations in the communication between EFA models and DES-P models (denoted by number 3). If there are both TFA and EFA models in the model of the whole system then all the six types of communications can be used between them (numbers 1-6) with the necessary changes of interpretations and representations.
2. Figure 2(b) – The ICT system is in the focus of the examination and the BP system is the environment for the ICT system. In this case the ICT system is modelled by a DES-IT model and the BP environment is modelled by an EFA model. The communication between cooperating DES-IT and EFA models is denoted by number. If there are TFA models in the model of the ICT system then types of communications denoted by number 1 and 4 are to be used too. (The question of change of representation and interpretation should be answered in these cases, too.)

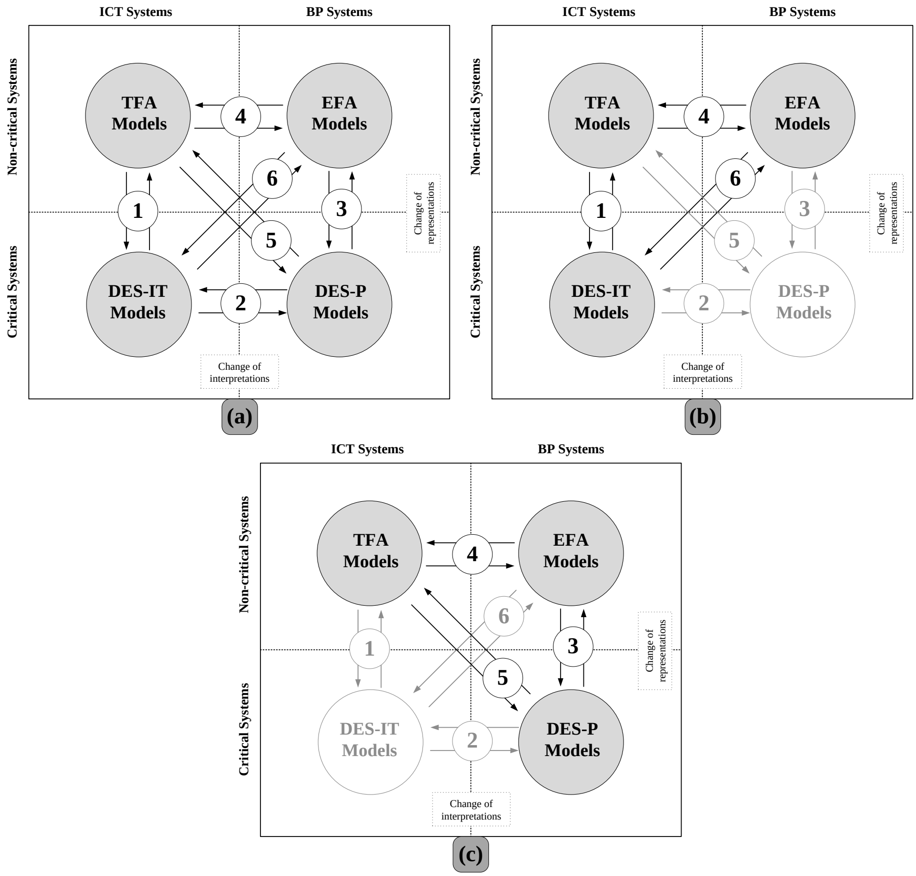

Figure 2. System-Model Matrices for Basic Configurations of Detailed Modelling

3. Figure 2(c) – The BP system is in the focus of the examination and the ICT system serves as the environment for the BP system. In this case the BP system is modelled by a DES-P model and the ICT environment is modelled by a TFA model. The communication between cooperating DES-P and TFA models is denoted by number 5. If there are EFA models in the model of the BP system then the types of communications denoted by number 3 and 4 are to be used too. (Of course, the question of change of representation and interpretation occurs in this case, too.)

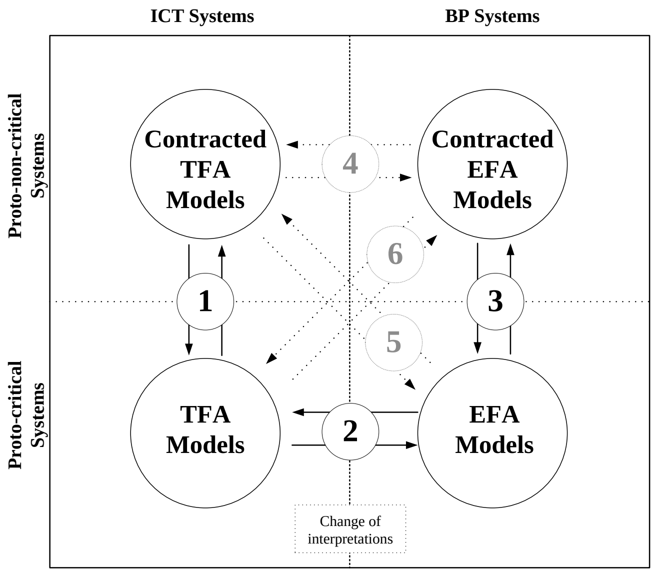

Figure 3 The System-Model Matrix for Preliminary Modelling

4.2. System-model matrix of cooperation for preliminary modelling

In the preliminary modelling stage, we have only a preliminary view of the criticalness of a system. For preliminary categorisation of systems we use the *proto-critical* and *proto-non-critical* classification.

In the system-model matrix for preliminary modelling (Figure 3) we have only two different types of fast models: we have TFA models to model proto-critical parts of ICT systems and EFA models to model proto-critical parts of BP systems and *contracted* TFA and EFA models to model proto-non-critical parts of ICT and BP systems respectively. Between cooperating TFA and EFA models there is a change of interpretations in communication (number 2 in Figure 3). In the cooperation between contracted and non-contracted models there is no change of representations in communication (number 1 and 3 in Figure 3). (Connections number 4-6 are theoretically possible, but have no practical significance in preliminary modelling [20]).

5. On Defining the Basic Configurations of Modelling and Simulation

What can help us in defining the *basic configurations* in preliminary and detailed phases of modelling and simulation? The question may also be formulated as how the *focus* of the analysis (ICT and/or BP) and how the *criticality of systems* (or part of systems) can be determined.

Modified Conceptual Models are planned to be used as a model design support tool in different phases of the simulation process of ICT and connected BP systems: in the phase of *preliminary modelling* ("Defining goals" and "Gathering and analysing data" stages) and also in the phase of *detailed modelling* ("Model design and model building" stage) [18]. The results of *time decomposition* in the common IT-P models may be used to define both the *focus* of the examination and the *criticality* of systems. According toe this approach, if the execution time ("time consumption") of a *subsystem* in an *execution-path* – which plays the role of a *key factor of performance of some system function* with a required low response time – is high then this subsystem may be evaluated *critical* [14],[19].

According to *Problem Context Retrieval Approach* [17] the results *of problem situation analysis* show the systems (ICT) and human (BP) *impacts* on the performance in an organisation helping to determine this way the *focus* of the analysis. The intensity of use of organisational processes helps to decide about the question of *criticality*. The method of the *System of System Failures*, described in [24], may be used as a complementary method for the Problem Context Retrieval Approach in the assessment of the impacts of system failures, in order to avoid the introduction of side effects.

For the organisational processes, methods based on *risk assessment* may also be used to outline the *focus* of modelling and to define the *criticality* of systems (e.g. [3], [25]).

For the ICT systems, the multi criteria decision approach described in [29], [30] – allowing to evaluate the effects of faults of info-communication networks occurring at the end users of the network – could be used to define the *focus* and *criticality* for the analysis and modelling.

6. Summary

This paper tackles with the problem of efficiency improvement of simulation of interconnected ICT and BP systems by using the combination of fast and detailed modelling methods in different phases of the simulation process.

First, the basic features of the detailed, fast and fast contracted modelling methods of ICT and BP systems (DES-IT, DES-P, TFA, EFA, contracted TFA and EFA) are summarised.

Then, the problem of the diversified assignment of fast and detailed modelling methods is analysed. According to the proposed the diversified assignment method, an appropriate set of detailed (DES-IT, DES-P), fast (TFA, EFA) and simplified fast (contracted TFA and EFA) modelling methods are used in a way that they increase the efficiency of simulation. The methods are selected taking into account the criticality of systems (part of the system) to be simulated, the required and efficient modelling resolution and the current phase in the process of simulation.

Next, the affect of the diversified assignment on the cooperation requirement of models was examined. The basic model configurations of ICT and BP models systems for the preliminary and detailed modelling have been examined and the types of necessary interactions between models have been described.

The results formulated in this paper have been fruitfully used in real-life projects [17], [23].

The approach proposed by the paper is generally applicable for the of any ICT/BP system because no domain-specific restrictions have been used.

We conclude that the proposed modelling methods based on the diversified assignment of cooperating rapid and detailed models in the preliminary and in the detailed modelling phases highly increase the efficiency of the performance of simulation of interconnected ICT and BP systems.

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