COOPERATING MODELLING METHODS FOR PERFORMANCE EVALUATION OF INTERCONNECTED INFOCOMMUNICATION AND BUSINESS PROCESS SYSTEMS

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ABSTRACT

This paper describes how the rapid and detailed modelling and simulation methods can be used to increase the efficiency of mixed simulation projects initiated to support the design of interconnected ICT (Information and Communication Technology) and BP (Business Process) systems. A system of cooperating rapid and detailed methods for critical and non-critical parts of systems is introduced in the phase of preliminary and detailed modelling. The method of translation of information of conceptual models that had been built prior to simulation is described, too. New methods using rapid models to model the ICT and BP systems functioning as environment for the detailed models are presented. A novel method for preliminary modelling based only on cooperating system of rapid models is described.

INTRODUCTION

Simulation projects aimed at supporting the design of Information and Communication Technology (ICT) systems and Business Process (BP) systems in an organisation are usually separate projects but these systems may have significant influence on each other, therefore common analysis of these systems in *mixed simulation projects* may have advantages. In mixed simulation projects we need to have methods appropriate for both types of systems: we need models of ICT and BP systems that can *interact* with each other just as these systems interact with each other in the real world.
The efficiency of the modelling and simulation process is influenced by two main components: the tool dependent and the tool independent component. The *tool dependent* component means the simulator and its services (how the models can be built, how the experimenting and debugging is supported, etc.). This approach is well introduced in (vom Lehn at al. 2008). By *tool independent* component we mean the set of modelling and simulation methods, as they can be implemented in any simulation environment. In this paper we will focus on some of these methods.

Discrete-Event Simulation (DES) can be used for detailed and accurate analysis and performance evaluation of ICT systems (Jain 1991) and BP systems. 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),* which is a combination of simulation and statistical approaches (Lencse 2004), was proposed for the *rapid modelling* and *preliminary* performance estimation of ICT systems.
The *Entity Flow-Phase Analysis (EFA),* which was derived from TFA, (Lencse and Muka 2006) is a method for the rapid modelling and preliminary investigation of BP systems.
In the case of large and *complex* systems, with which we may be easily faced in mixed simulation projects, the necessary computing capacity may reach the power of a supercomputer. Traditional *parallel simulation* methods (Parallel Discrete Event Simulation, PDES) (e.g., conservative, optimistic) (Fujimoto 1990) can rarely provide an attractive speed-up (Pongor 1992).
In mixed simulation projects, the *combination of cooperating detailed (DES-IT, DES-P) and rapid (TFA, EFA) models and methods* based on the outputs of *Modified Conceptual Modelling* (MCM), may give the required increase of efficiency. (Modified Conceptual Modelling (Muka and Lencse 2006), which is a method of merging hard-systems and soft-systems approaches, is a powerful model design support tool in simulation projects.)

SYSTEM-MODEL MATRICES

System-Model Matrix of Cooperation for Detailed Modelling

In the system-model matrix for detailed modelling (Figure 1) there are 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). We also show the cooperation between systems (denoted by numbers 1-6 in Figure 1).

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

1. 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 (number 2 in Figure 1). 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 (number 1 in Figure 1). In case the 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 (number 3 in Figure 1). 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 (number 1-6 in Figure 1) with the necessary changes of interpretations and representations.

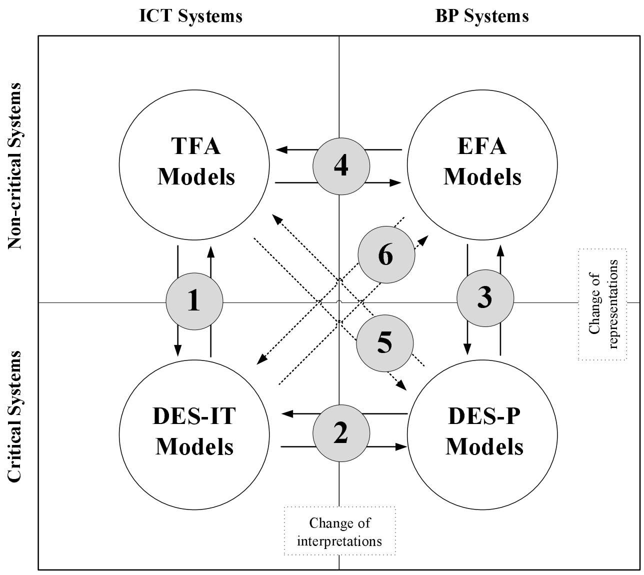

Figure 1 The System-Model Matrix for Detailed Modelling

2. 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 6 in Figure 1. (The question of change of representation and interpretation should be answered in this case, too.)
3. 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 in Figure 1. (Of course, the question of change of representation and interpretation occurs in this case, too.)

System-Model Matrix of Cooperation for Preliminary Modelling

Preliminary modelling is a very important approach in the simulation process of *complex* systems. *Preliminary models* and results may inform the users about the quality and scope of final results and may introduce the possibilities of the simulation method in an early stage of the simulation project. It may support *efficient decision making* on the objectives of the project, to get information about the necessary inputs (it may help to define the data collection need more precisely, to identify and analyse sources of data), to reveal the direct and potential users of simulation results (it may help in the identification of the set of systems influenced by the simulation).

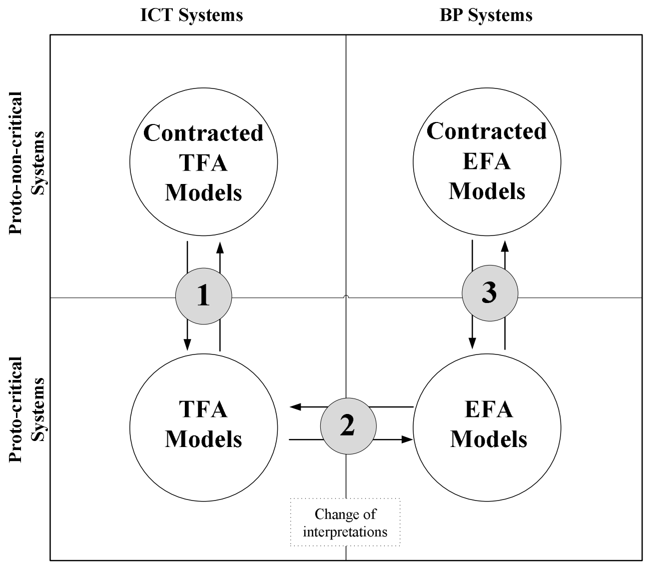

Figure 2 The System-Model Matrix for Preliminary Modelling

As for preliminary modelling, it is the best to apply the *principle of parsimony* (Pidd 1991); ie. that the final simulation model should be built in incremental steps starting from a non-complicated model.

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 2) we have only two different types of rapid 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*[1] 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 2). In the cooperation between contracted and non-contracted models there is no change of representations in communication (number 1 and 3

[1] The term *contracted* will be defined in section "Designing Cooperation of Models: Preliminary Modelling"

in Figure 2). (The reasons will be explained later.) Connections number 4-6 are theoretically possible, but have no practical significance in preliminary modelling.

DESIGNING COOPERATION OF MODELS: TRANSLATION OF CONCEPTUAL MODELS

Conceptual Modelling

Conceptual models planned to be used as a *model design support tool* (Muka and Lencse 2006) in different phases of simulation projects (in our examination: *mixed simulation projects*): in the phase of *preliminary modelling* ("Defining goals" and "Gathering and analysing data" points of the simulation method) and also in the phase of *detailed modelling* ("Model design and model building" point of the simulation method). Therefore, **it is crucial how the information acquired in conceptual modelling can be translated into the set of cooperating rapid and detailed models**.

First, let us summarise the essence of conceptual modelling:

The central idea of SSM (Soft Systems Methodology, Checkland 1989) is the *conceptual model*. The outcome of SSM may also be used for information system analysis and design (Curtis 1989; Gregory 1993).

The main elements of conceptual models are *key activities* representing *subsystems* of the system. The selected set of subsystems with their logical connections is the conceptual model. The set of conceptual models with defined connections among them form a system of conceptual models. A hierarchy of conceptual models can be found when replacing a first-level conceptual model of a subsystem with its detailed conceptual model.

In our previous paper (Muka and Lencse 2006), we have described the *modified conceptual modelling (MCM)*. MCM may be characterised as an *extension* of SSM models with *extra* features and *grafting* the methods of using extended models into SSM. MCM, which is focusing on the design of information systems in an enterprise, is applicable both on soft-system level and on hard-system level of simulation model design (Muka and Lencse 2007a).

In an MCM, a key activity is performed generally by a Business Process (BP) function or by an ICT system function, that is, any function in an enterprise can be performed by some relevant business process (P subsystem) with its human resources or by some relevant ICT system (IT subsystem) with its technical resources. Thus, MCM elements can be P-type or IT-type depending on what they represent, BP or ICT system function. (This is the basic feature of *MCM* that makes it applicable in *mixed simulation projects*.)

An important feature of MCM is that any IT element in the model should be connected to at least one P element in order to have its human resource connection.

For the analysis of necessary and sufficient conditions in MCM, three element types are used: F, C and A, that is, PF, PC and PA for processes and ITF, ITC and ITA for IT systems.

F (*function*) is an element performing basic function in the system; element C (*condition*) is providing a condition function necessary to perform the basic function while A is an *agent* element ensuring the sufficiency ("motivational") condition for the basic function to be completed.

Virtual time in modified conceptual models is a time sequence assigned to an MCM by giving time labels to its elements. The virtual time of different MCMs may also be *synchronised* through transient edges (logical connections between MCMs) and condition elements. In virtual time of MCMs the question of *time decomposition* may also be examined (Muka and Lencse 2007b).

Interpretation of MCM Analysis Results

MCM analysis, which is a complete set of methods grafted into SSM, is used for system analysis. After finishing the MCM analysis, the designer has a lot of information about the systems to be modelled and simulated, which may be summarised as follows:

- There has been built a set of conceptual models of IT and P subsystems, the functions of subsystems has been described and the type (A, F, and C) of every subsystem has been determined.
- The connections between subsystems have been identified.
- The virtual time system of subsystems has been assigned and synchronised.
- The execution time of subsystems has been found out (as a result of the time decomposition) together with the fitting of execution time of different types of subsystems and the set of critical IT and P subsystems have been defined.
- For the time decomposition, a simulator may have been used and pre-assumptions on sequential-parallel simulation of subsystems may have been produced.
- The resolution of the conceptual model has been set (completing the resolution increasing-decreasing transformations).

At this point, before starting the translation of conceptual models, the question whether all the IT subsystems are explicit should be decided (P subsystems may contain hidden IT subsystems when extended).

Problems of Translation: A Customer Request Processing System

In the following, by describing the example of a Customer Request Processing System (Figure 3), the questions of translation of results of MCM analysis into ICT and BP models will be examined.

In the example, there is a Customer Help Desk, which handles the requests of users (using different ICT systems) and decides about the involvement of the Service Department. The Service Department processes and schedules the requests from the Customer Help Desk and direct alarm requests from users, also using ICT systems. The VoIP Service Department provides VoIP services to these systems according to the requirements of the service level agreement (SLA).

The conceptual models in the example are only conceptual model fragments, and do not try to present all the details of the systems.

There can be many questions that can be examined in the introduced situation. For example:

- Optimisation of resources used in Service Department, taking into account the requirement of increased user satisfaction
- Efficient division of work between an “Automatic customer request answering and processing software system” and the operators of the Service Department
- The required change in the structure of the Service Department to achieve the shortest reaction time
- To determine an appropriate SLA (Service Level Agreement) for VoIP between Service Department and the departments using the services
- Satisfactory and efficient intranet capacity for green number of services, VoIP services and direct user alarm services

Now, let us see the example MCMs in detail:

In Figure 3, the Customer Help Desk receives a Customer Request from a General User. The “Automatic request answering and forwarding” (ITF_1 subsystem) of the Customer Help Desk handles the request using IT subsystems (ITC_{11} and ITC_{12}) providing the necessary service conditions.

In the next fragment of Customer Help Desk model the customer request that was forwarded by the “Automatic customer request answering and forwarding” subsystem is received by help desk operator (PF_i subsystem) using VoIP (condition provided by ITC_i subsystem) and customer information asked from CRM (Customer Relationship Management) (PC_{i+1} subsystem) to continue processing by subsystem PF_{i+1} and to decide about involving Service Department. PF_{i+2} may involve Service Department using VoIP services (Transient 1).

The Service Department receives Transient 1 (subsystem $PC_{(j+1)2}$) and processes the request from Customer Help Desk (subsystem PF_{j+1}). The PF_j subsystem of the Service Department manages the resource pool (using a Workflow Management System provided by PC_j subsystem).

The Direct User is able to send direct alarm request to the Service Department. The request (user alarm signal in this case) is received by $PC_{(j+1)1}$ subsystem.

Let us notice the difference: a General User reaches the Help Desk through a green number service (subsystem ITC_u in the MCM of the General User) but a Direct User has a special subsystem (subsystem ITC_{d+1} in the MCM of the Direct User) for the access.

The VoIP Service Department is responsible for granting the VoIP service for the Customer Help Desk and for the Service Department. In the MCM of the VoIP Service Department shown model fragments are shown of P (PF_p and PF_{p+k}) and IT (ITA_v, ITF_v, ITC_v) subsystems of the system providing VoIP services.

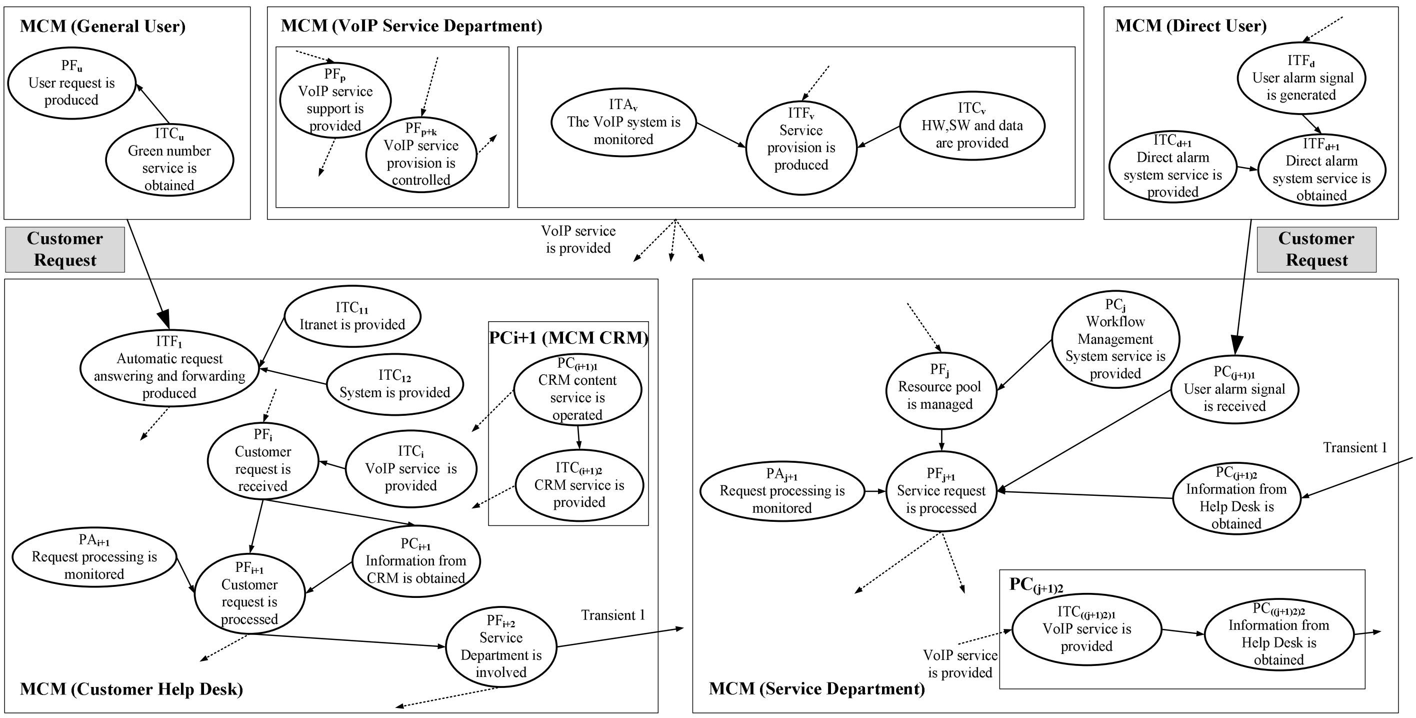

Figure 3 Fragments of the Modified Conceptual Model of a Customer Request Processing System

P subsystems with Hidden IT systems

- The PC_{i+1} conditional subsystem provides the necessary customer information for subsystem PF_{i+1} for request processing. In the expanded PC_{i+1} subsystem there are two subsystems: the $PC_{(i+1)1}$ process subsystem and the $ITC_{(i+1)2}$ IT subsystem. Both subsystems have their own output that means that PF_{i+1} may send direct request to the CRM database or in case of a more complicated inquiry the CRM operators may be asked.
- The situation is similar in the case of PC_j in the Service Department, where PF_j uses a Workflow Management System for resource pool management.
- The $PC_{(j+1)1}$ subsystem receives the alarm signal from a Direct User. Of course, in this subsystem there should be an ICT part (the Direct User has

direct access to the Service department, through for example some devices connected to a leased line) but there is a special process part, too.

- The $PF_{i+2} - PC_{(j+1)2}$ connection uses VoIP services (see expanded $PC_{(j+1)2}$ subsystem in MCM of Service Department). The number of channels (rate of successful calls), which may have influence on the reaction time of the whole Customer Request Processing System, may be important for this connection.

Determining ICT-BP Interactions in Conceptual Models
By examining conceptual models, the *interactions* between planned simulation models of ICT and BP systems can be identified.

1. An activity of the BP system uses the ICT system:
   - PF_i may be performed if PC_i is provided
   - PF_{i+1} may be performed only if PF_i asks for information from CRM and the necessary information is obtained by CRM (PC_{i+1})
   - PF_j may be performed with the condition provided by PC_j
2. An activity of the BP system sends information to another activity of the BP system using the ICT system:
   - The P subsystem of Customer Help Desk (PF_{i+2}) sends a message to another P subsystem of service Department ($PC_{(j+1)2}$) using the IT subsystem $ITC_{((j+1)2)1}$
3. The ICT system acts as an initiator towards the BP system:
   - A user alarm generated by subsystem ITF_{d+1} of the Direct User generates entities for the processes modelling P subsystem $PC_{(j+1)1}$
   - ITF_1 acts as initiator for PF_i (and may also for other subsystems)
   - The ICT system acts as an initiator towards the BP system:
4. The BP system acts as an initiator towards the ICT system:
   - The P subsystem PF_u of General User acts as an initiator for ITF_1 of Customer Help Desk

Remark:
Of course, depending on the designers view, the type of interaction may change. For example: PF_u of a General User may send a message to PF_i of Customer Help Desk using IT subsystems (ITC_u, ITF_1, ITC_{11}, ITC_{12}, ITC_i, and others).

Points to Consider for Translation

The following points that can help in translating decisions:

Critical F subsystems (or a C subsystem evaluated as critical in the MCM analysis) will probably be translated into detailed ICT or BP models.
Those elements that are part of critical connections can probably be translated into detailed ICT or BP models.
Non-critical (including environmental C (and A)) subsystems will be translated into TFA and EFA models or their function may be approximated statistically if it satisfies the accuracy requirement.
P elements in the set of critical subsystems or connections should not contain hidden IT elements, that is, these P subsystems should be expanded during the translation.

DESIGNING COOPERATION OF MODELS: RAPID AND DETAILED MODELS

DES-IT and DES-P models are detailed models of ICT and BP systems, thus they are typically applied in *detailed modelling phase* of simulation projects.
For the cooperation of DES-IT and DES-P models (connection number 2 in Figure 1), it is not enough simply to switch from messages in DES-IT to entities in DES-P, but it is necessary to *change interpretations* between them. To develop the change of interpretations the basic *interactions* are identified (number 1-4 in "Determining ICT-BP Interactions in Conceptual Models") between DES-IT and DES-P models.
If it is useful to divide the ICT system into critical and non-critical parts the TFA method is used to model the non-critical part. During the cooperation of DES-IT and TFA model (number 1 in Figure 1) there is a need for the bidirectional change in representations that is a conversion between different traffic representations — messages and statistics. In the DES-IT segment it is necessary to collect the appropriate statistical characteristics of the message flow (which can be characterised by e.g. message length, inter-arrival time, the sources and destination of the packets, etc.) in order to produce the statistics that are used in TFA. In the direction from the TFA model to the DES-IT model messages should be generated on the basis of statistics (traffic model in TFA).
The same consideration can be taken into account concerning DES-P and EFA models (number 3 in Figure 1), where only an entity flow is used in DES-P instead of message flow in DES-IT and entity-load model in EFA instead of traffic model in TFA.
Of course, if there are TFA and EFA models in the model of the whole system then there can be direct cooperation between them (number 4 in Figure 1). The rules of cooperation between TFA and EFA models may be found using communications for traffic representations (1 and 3 in Figure 1) and connection for change of interpretations (2 in Figure 1). These rules can be used during simulation (Lencse and Muka 2007a).
If there is only one non-critical part in the model (TFA or EFA) (*asymmetrical non-critical situation*) then communication number 6 or 5 should be used in case of existing traffic to DES-P or DES-IT. The rules of cooperation may be revealed using the approach from the previous symmetrical case, fitted to this situation.
If there is a model (DES-IT or DES-P) of a critical system and a model of its non-critical environment (EFA and TFA respectively) in the model then only communication used for cooperation is 6 (or 5 respectively) in Figure 1. This cooperation may be prepared in the way described previously, in the case of asymmetrical non-critical systems.
When is it worth modelling ICT and BP systems together?

Let us see some examples:

- BP model in ICT model: The BP system (with a non-predictable behaviour) is an intensive traffic source for the ICT system (for example customer service offices in the ICT infrastructure).
- ICT model in BP model: for example the optimisation of proportion of automatic (produced by an answering software) and operator performed activities of a help desk system.
- ICT and BP model: for example to set up the most efficient SLA (Service Level Agreement) for a service department of a complex ICT system.

If there is a close relationship between the ICT and BP models the best way is to organise them into *one process* or if it is not possible then to find an efficient way of s*ynchronisation* of the models.

If there is a TFA (or EFA) model in the model (to model non-critical parts of the system) it can be synchronised with the critical DES-IT (or DES-P) model in the ways described in (Lencse 2004).

In case of *asymmetrical non-critical situation* or if there is a critical DES-IT (DES-P) model and a non-critical EFA (TFA for DES-P) in the model of the system, the above mentioned methods may be used, but the problem of change of representations and interpretations should not be forgotten.

IF there are only TFA and EFA models in the model of the system, the synchronisation seems to be simple (both TFA and EFA are snapshots of operation of the system) but we have only limited possibilities because we do not have information about the models' virtual time.

The essence of building cooperating models can be summarised as follows: If we have a set of different models and we would like to cooperate *any two of them* we must build the models in the way that they can cooperate (to produce and send all the information necessary to the other model) or to formulate this principle in a more general way, if there is a chain of cooperation (for example a *chain* of DES-IT, DES-P, EFA models) the system of conversions in the model chain and the models themselves should be built in a way that they should keep, regenerate and generate all the information necessary in the chain of conversion and models.

DESIGNING COOPERATION OF MODELS: PRELIMINARY MODELLING

In the application described in (Lencse 2004), cooperating DES and TFA models are used for different parts of the same a system (DES is used for modelling the critical part TFA is used for modelling the non-critical part of the modelled systems).

In preliminary modelling, which is our case, it is appropriate to use rapid models for modelling the whole system (both for ICT and BP systems and for critical and non-critical parts).

The *testing step* of the TFA/EFA spatial phase (Lencse and Muka 2007b) uses DES models to reveal routing properties of models of subsystems. That is, to perform this step, DES models of subsystems should be built. Keeping to the rule of parsimony we should reuse this DES model: the same *testing phase*[2] is used for collecting statistics about the communication between DES models of ICT (and BP) systems, about message flows in the ICT system and about entity flows in the BP system. The same testing phase collects information for setting up the conversion (interpretation) rules between ICT and BP parts.

The use of MCM time decomposition results about sequential-parallel processing support (Muka and Lencse 2007b) may help to speed up the model building and testing phases.

In (Lencse and Muka 2008) the terms *inflated / deflated models*[3] were introduced.

In the test phase we use *inflated* DES-IT and DES-P models, in the model running phase we use TFA and EFA models, which are *deflated* DES-IT and DES-P models. The deflated models use "inflated communication" ie. message flow (or entity flow) in virtual time. (The concept of communication is shown in Figure 4.)

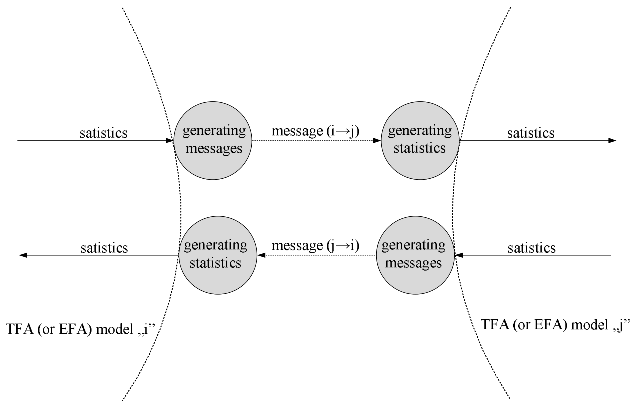

Figure 4 The Concept of Connecting TFA (or EFA) Models

A system of deflated models with deflated internal communications we call *contracted model*.

The contracted TFA (or EFA) (Figure 5) models behave as one deflated TFA (or EFA) model.

For the communication of ICT and BP models, the change of interpretations (of message and entity flow) based on interactions between the modelled systems is necessary.

Now, let us examine the system of cooperation in preliminary modelling (Figure 5).

$TFA_{1-n,}$ EFA_{1-m} models are the models of the proto-critical parts of ICT and BP systems respectively. $TFA_{a(1<a<n)}$ (or $EFA_{b(1<b<m)}$) is the model of a key activity produced by a proto-critical ICT (or BP) subsystem "a" (or "b") (of course TFA_a (or EFA_b) may be a contracted, proto-non-critical model too).

[2] RDT (Routing Decision Tree) building phase (Muka and Lencse 2007b)

[3] In a nutshell, if a compound module is inflated, its internal structure as well as the operation of its parts are modelled in detail. If it is deflated, we omit its internal structure and operation and imitate its behaviour for the outside world by a simpler algorithm that acts similarly but of course not completely the same as the original compound module.

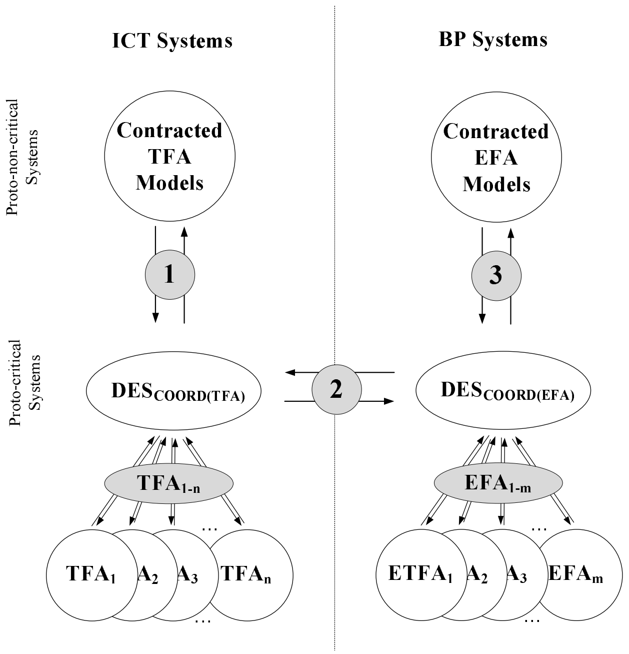

Figure 5 TFA and EFA Cooperation in Preliminary Modelling

The non-contracted TFA/EFA models may be built as follows:

1. Set up the required model resolution using MCM resolution transformations (grouping, integrating).
2. Create DES models of subsystems.
3. Collect statistics in the TFA/EFA test phase between subsystems of the proto-critical systems and between the proto-critical and proto-non-critical system parts, too.
4. Set up S_{RU} (size of routing unit, (Lencse and Muka 2007b)) for each TFA/EFA subsystem model.

The contracted TFA/EFA models may be built as follows:
(Contracted TFA/EFA models are the models of the environment One contracted TFA model is to be built for the ICT environment and one EFA model for the BP environment.)

1-3. The steps from 1 to 3 are the same as the steps of building non-contracted models.

4. Contract the model: Make one TFA/EFA model from subsystem models. While each element of the system of the non-contracted TFA/EFA models (TFA_{1-n}, EFA_{1-m}) has its own virtual time, the contracted part uses the same virtual time (and the same S_{RU}).

The operation of the contracted and non-contracted TFA/EFA models is coordinated by DES_{COORD} element's functions. A DES_{COORD} performs the following tasks:

- Manages the virtual time system of models (starting from the conversion of the MCM virtual time system).
- Manages the connection map and the communication of TFA/EFA models.
- Controls the work of the contracted and non-contracted models. (Contracted and non-contracted TFA/EFA models of the preliminary model work in the same way.)
- Manages the communication (bidirectional interpretation) between ICT and BP parts.

The *preliminary model with cooperating TFA and EFA models* works as follows (while the TFA/EFA runs the virtual time will not elapse, but the result will have influence on the virtual time of the whole process):

- At t_0 $DES_{COORD(TFA)}$ and $DES_{COORD(EFA)}$ prepare starting conditions and starting messages:
  - After message → statistics conversion a set of models from TFA_{1-n} and contracted TFA may be started to run by $DES_{COORD(TFA)}$ and a set of models from EFA_{1-m} and contracted EFA may be started to run by $DES_{COORD(EFA)}$.
  - An interpretation cycle may be started (messages → interpretation → interaction → messages → statistics.
- At $t_0+\Delta t_i$ the selected TFA (or EFA) model starts running.
- At $t_0+\Delta t_i+\Delta t_k$ the selected TFA (or EFA) model returns statistics.
- At $t_0+\Delta t_i+\Delta t_k$ $DES_{COORD(TFA)}$ and $DES_{COORD(EFA)}$ starts statistics → message conversion.
- At t_j information interchange may be initiated between ICT and BP models (if necessary).
- At t_l $DES_{COORD(TFA)}$ (or $DES_{COORD(EFA)}$) gets back interaction information and starts interaction → interpretation → messages → statistics conversion.
- And so on.
- Finish when the time for examination elapsed or the answer is produced.

ICT and BP may by run in two processes:

- ICT part in one process, BP part in another process,
- A suitable synchronisation algorithm is used between ICT and BP parts.

CONCLUSIONS

This paper addresses the problem how the system of cooperating rapid and detailed modelling and simulation methods can be used to increase the efficiency of mixed simulation projects initiated to support the design of interconnected ICT (Information and Communication Technology) and BP (Business Process) systems.
First, the general features of cooperation of rapid and detailed modelling methods in the phase of preliminary and detailed modelling are introduced using *system-model matrices.* Both ICT and BP systems may have critical and non-critical parts in the detailed modelling phase and respectively proto-critical and proto-non-critical parts in the phase of preliminary modelling.
The next part describes the method of translating information obtained in the phase of conceptual modelling for building the system of cooperating rapid and detailed models. After a brief summary of general aspects of conceptual modelling, the essence of using MCM (Modified Conceptual Modelling) in *mixed* (ICT and BP) *simulation projects* (including general aspects of conceptual modelling) is explained. An example is shown to introduce the tasks of translating the results of MCM analysis by analysing the

problem of hidden IT systems and the problem of determination of ICT-BP interactions.

Then the questions of cooperation in the phase of detailed modelling are analysed. An evaluation is given of the methods of representation, interpretation and synchronisation of cooperating models. *Two new methods* are introduced: how to use rapid BP models that function as environment in detailed modelling of ICT systems and also how to use rapid ICT models functioning as environment in detailed modelling of BP systems.

Finally, a *novel method* for preliminary modelling based only on cooperating system of rapid models is described. In the proposed method a *contracted* rapid model is used to model the proto-non-critical parts of the system and a set of rapid models is used to model the proto-critical part of the system. A coordination element is used to deal with timing and conversion problems (messages and statistics generation and control of interaction of systems).

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

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BIOGRAPHIES

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