DEVELOPING A META-METHODOLOGY SUPPORTING THE APPLICATION OF PARALLEL SIMULATION

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ABSTRACT

New concepts are described to SSM (Soft Systems Methodology) conceptual models, which are tools for system analysis supporting the application of simulation including decisions about parallel simulation in an organisational environment. A meta-methodology facing with unstructured problems in simulation projects and also supporting parallel simulation is formulated.

INTRODUCTION

Simulation projects initiated to support Information and Communication Technology (ICT) system design and Business Process (BP) design in an organisation usually begin with an unstructured problem situation, where frequently there is on opinion that simulation takes a lot of time and requires significant resources to be assigned with the risk of getting no useful results.

In this paper we outline a meta-methodology addressing these problems: we develop a soft approach to support problem-structuring and effective goal definition to build useful models and also increasing efficiency by precise localization of systems to be modelled and by supporting decisions on the use of *parallel simulation* helping in speeding up the simulation.

In this paper we introduce new concepts to SSM (Soft Systems Methodology, Checkland 1985, 1989) conceptual models then using the new concepts and a traditional six-step process of simulation methodology we outline a *simulation meta-methodology*.

Ideas about N&S (Necessary & Sufficient) conditions and "temporal relations" of conceptual models described by Gregory (Gregory 1993) are used as starting point in our paper.

In (Sierhuis and Selvin 1996, Sierhuis and Clancey 2002) there is a description of *a framework for collaborative modelling and simulation* using SSM and a set of four methods to cover the modelling activities. The main problem with this approach is that there is a *methodological gap* between SSM and methods to deal with simulation.
In our approach this methodological gap is eliminated by the development of modified conceptual models.

DEVELOPING MODIFIED CONCEPTUAL MODELS

The Seven-stage Process of Traditional SSM

Checkland's SSM is an approach to apply systems-thinking to ill-defined problems in human activity systems. It is also described as a system-based problem-solving methodology starting with the unstructured problem situation. By the outcome it is also defined as a learning system, a system for Operational Research or a method for information system analysis and design (Curtis 1989).

Stages of SSM are shown in Figure 1. The process of SSM seems to be linear: it is a sequence of well-defined stages and there is a progression from one stage to the next in the methodology. Working with SSM is an iterative process, since it may be necessary to re-enter an earlier stage for re-execution.

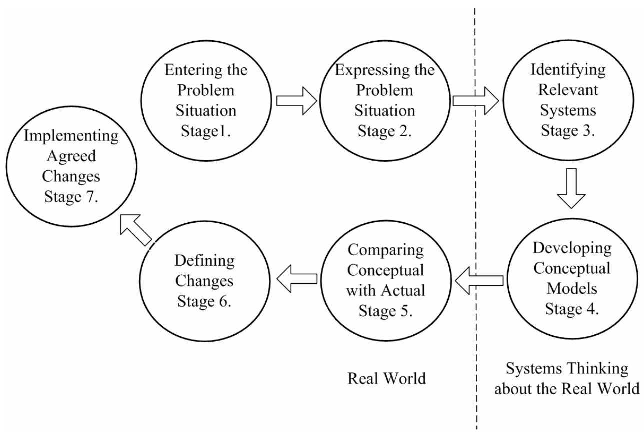

Figure 1. The Seven-stage Process of SSM

In Stage 1 and 2 there is a finding out about the unstructured problematical situation that is entering and expressing the problem situation.

In Stage 3 relevant human activity systems are identified and using CATWOE analysis (Checkland 1989) root definitions of selected systems are formulated.

In Stage 4 there is the conceptual model-building of relevant systems from the root definitions provided in Stage 3. Conceptual models are models of the views of what exist and not models of what exist in the real world. In a conceptual model key activities of the system are taken into account. A key activity itself generally represents a subsystem (Curtis 1989) that would carry the activity out, thus a hierarchy of conceptual models can be defined when replacing a first-level conceptual model of a subsystem with its detailed conceptual model.

In Stages 4 - 7 there is a comparison with the real world to define necessary and feasible changes and to define actions to implement changes.

In the following points we harden up the methodology (Jackson and Keys 1984) by introducing new concepts into the conceptual models.

Function elements in Conceptual Models

In this paper we focus on the design of information systems in an organisation therefore we may suppose that a key activity is performed in general by an OP (Organisational Process) function or by an ICT system function. In other words it may be said that any function in the organisation can be performed by some relevant organisational process (P subsystem) with its human resources or by some relevant IT subsystem with its technical resources.

Thus the subsystem elements in our conceptual models can be P-type or IT-type; depending on they represent OP or ICT system function.

In our approach, an important feature of IT elements (according to the traditional approach of SSM) is that any IT element in the model should be connected to a minimum of one P element in order to have its human resource connection. We may look at the conceptual model as a directed graph CM(N;E), where N is the set of nodes containing P-type or IT-type elements, E is the set of directed edges. In order to define the connected feature of IT elements we introduce a logical variable CON to describe that nodes x and y of graph CM are connected:

$$\mathrm{CON}\begin{cases} = 1, \text{ if } (x;y) \in E \text{ or } (y;x) \in E \\ = 0, \text{ otherwise} \end{cases}$$

where $x \in P \cup IT$ and $y \in P \cup IT$

Now it may be said about IT elements:

$\forall IT_i$ (i=1;2;…;I) $\exists j$ (j=1;2;…;J)
(where I is the number of elements in the set IT, J is the number of elements in the set P)

$CON(IT_i;P_j)=1$

To describe the set of N&S conditions (Gregory 1993) we define three element types F, C and A, It means that there can be PF, PC, PA, ITF, ITC and ITA elements. PF is an element performing basic function in the system; PC is providing conditional function necessary to perform basic function while PA is an agent element ensuring the sufficiency for the basic function to be completed. ITF, ITC and ITA also perform subsequently basic, conditional and agent function, taken into account IT elements' connected feature.

In general, a function is performed if it is assigned to an existing or a new organisational process and the necessary organisational resources (roles and responsibilities) are assigned to the process. It means that using a PA is necessary only in special cases: in the case if the necessary process resources are not assigned in a PF and its PCs elements (for example the necessary resources are assigned in a shared way), or we want to examine the subsystem responsible for the resource assignment.

In the case of an information system design agents can also be IT-type elements, which are software and hardware resources.

Now let us see a short example. Figure 2. shows a conceptual model of a Customer Request Processing System. After receiving the customer request by PF_1 its processing is performed by PF_2, using information obtained by PC_1 from CRM (Customer Relationship Management) database. Customer request is scheduled by PF_3 (service activity assigned to customer request) using schedule information obtained by PC_2 from service department, which is in another system. Answering the request is performed by subsystem PF_4.

PA_1 and PA_2 are agent elements guaranteeing resources for functions in PF_2 and PF_3 to be performed.

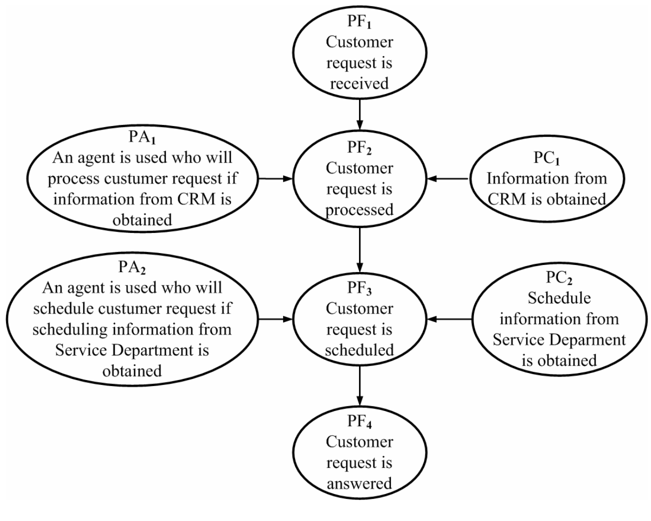

Figure 2. Conceptual Model with N&S Conditions after Identifying PA, PF and PC Elements

In Figure 3. there can be seen the model of the same system with one agent element PA_1. It was decided not to use PA_2 because in PF_3 and in PC_2 there is a sufficient assignment of resources and we do not want to examine the resource assignment subsystem.
We express N&S conditions in symbols for PF_2 and PF_3:

$PF_2 \Leftrightarrow (PF_1 \wedge PA_1 \wedge ePC_1)$
$PF_3 \Leftrightarrow (PF_2 \wedge ePC_2)$

In Figure 3. elements PC_1 and PC_2 are expanded (Checkland 1985). PC_1 contains subsystems $ITC_{1.1}$ (the CRM function subsystem) operated by $PC_{1.1}$. In PC_2 there are subsystems $ITC_{2.1}$ and $PC_{2.1}$. where $ITC_{2.1}$ can be an intranet system function and $PC_{2.1}$ a function to provide Service Department's scheduling information obtained using intranet function. The operating subsystem of intranet here is not examined.

The conceptual model CM in Figure 3. can be described as directed graph CM(N;E;TR) where TR is the set of transient edges. Transient edges connect elements in different conceptual models. (A conceptual model we got from an expanded element is also defined to be a different one.) In Figure 3. elements PC_1 and PC_2 are expanded. They contain P-type and IT-type elements in different configurations.

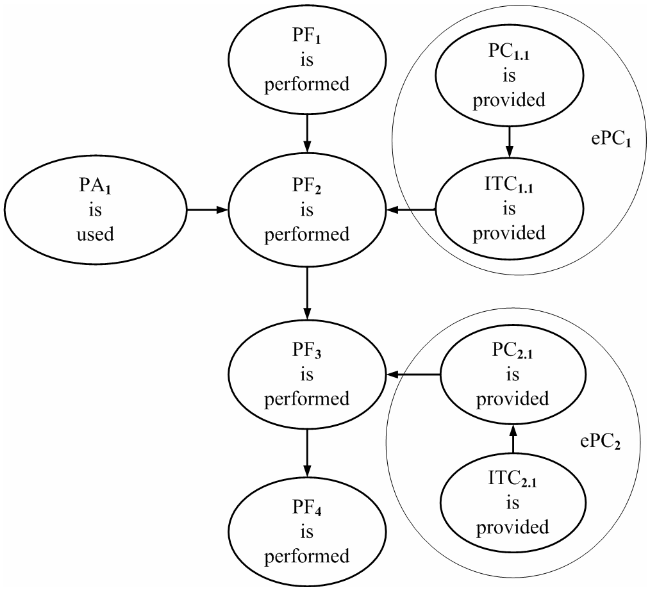

Figure 3. Conceptual Model with Expanded Elements

The expanded elements ePC_1 and ePC_2 are also conceptual models described by directed graphs $CM.ePC_1$ and $CM.ePC_2$ (CM denotes the original conceptual model). Edge $(PC_{1.1};ITC_{1.1})$ in graph $CM.ePC_1$ represents an operator-type connection while edge $(ITC_{2.1};PC_{2.1})$ in graph $CM.ePC_{1.2}$ shows a provider-type connection. An operator P element is responsible for a function of an IT element, while a provider P element is responsible for a function using an IT element. The transient edges $(CM.ePC_1.ITC_{1.1};CM.PF_2)$, $(CM.ePC_2.PC_{2.1};CM.PF_3)$ connect elements of expanded subsystems to elements in conceptual model CM.

Virtual Time and Synchronisation in Conceptual Models

Introducing time into the conceptual models can be done by assigning time label to elements. Giving time label T to an element has the meaning that the event of a 'function is performed' takes place at T.

A conceptual model's **virtual time** is a time sequence assigned to a conceptual model by giving time labels to elements. Time labels $T_{(i)}$ and $T_{(i-1)}$ have the meaning that a function with time label $T_{(i-1)}$ performed earlier than a function with time label $T_{(i)}$. (See in Figure 4.) There is nothing said about the measure $\Delta T= T_{(i)}- T_{(i-1)}$. (To give an estimate of ΔT, simulation method can be applied.)

In Figure 4. we show two conceptual models CM1 and CM2, where CM1 may be the Customer Request Processing System from our previous example and CM2 system performing services (Service Department).
CM1 and CM2 are connected with request and answer connections (RCM2-RCM1, ACM2-ACM1) which may be described as graphs' transient edges
$(CM1.PF_i;CM2.ePC_x.PC_{x(1)})$,
$(CM2.PF_u;CM1.ePC_v.ITC_{v(1)})$
RC (Request from Customer) and AC (Answer to Customer) are entry and exit edges of graph CM1.

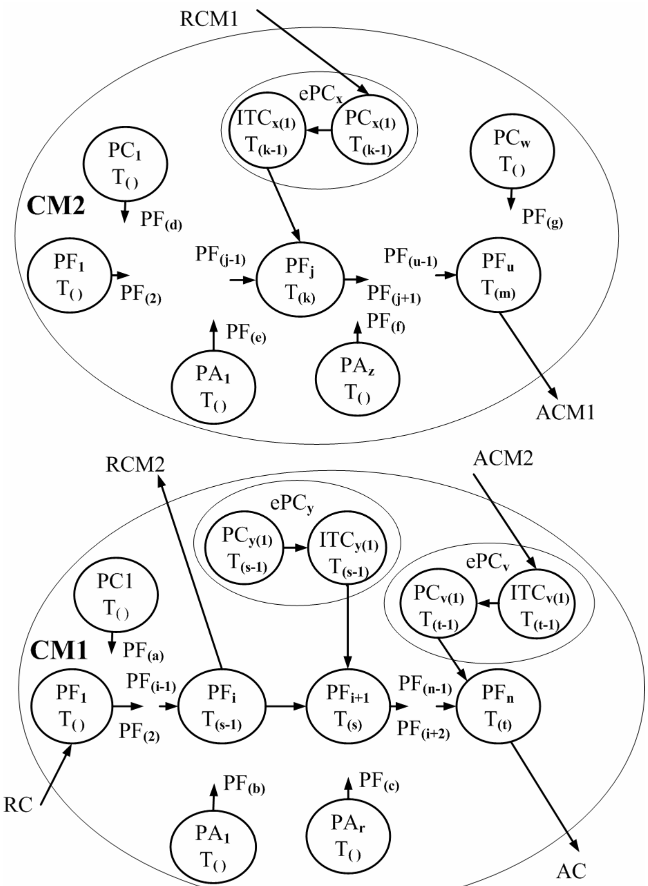

Figure 4. Synchronising Conceptual Models CM1 and CM2 through Conditional Elements

We remark that IT and P elements in expanded subsystems have the same time label. ($T_{( )}$ denotes a time label which is not significant in our analysis.)
Through transient edges and conditional elements (PC_x and PC_v) virtual times of conceptual models are **synchronised**. After synchronisation of CM1 and CM2 we have the next relations:

$T_{(s-1)}=T_{(k-2)}$ and $T_{(s-1)}<T_{(k-1)}$
$T_{(m)}=T_{(t-2)}$ and $T_{(m)}<T_{(t-1)}$

On the bases of synchronisation a decomposition of execution time of functions can be made.

CONSIDERATIONS ABOUT APPLICATION OF PARALLEL SIMULATION

Note: We have not used any constraints on the type of simulation (continuous, discrete, time-driven, event-driven, etc.) therefore our results may be used to the application of Event-driven Discrete-Event Simulation (DES) which is in the focus of our interest.
In the case of information system design after the IT and P function analysis, assigning virtual time and synchronisation of conceptual models, we can have a critical set of elements to be simulated.
The critical set may be an interconnected set of IT and P elements but practically it is a set of at least one IT element connected to one P element. This is the situation to consider parallel simulation.
In the case of one IT and one P subsystem, depending on the focus of the simulation there can be three basic parallel simulation decisions: (1) detailed simulation of both IT and P subsystems; (2) detailed simulation of IT system with simulated P as process environment; (3) detailed simulation of P with simulated IT system as environment. The P and IT parts can act as the two segments of parallel discrete event simulation. They can be executed parallel by two interconnected processors. For all the three situations the use of the Statistical Synchronisation Method (Pongor 1992) can be considered as an inter-processor synchronisation method if there is a relatively slow speed of changes in subsystems' states. In situation (3) the method of TFA (Traffic Flow Analysis) (Lencse 2001) may be appropriate. Methods for the parallel execution of the Combined DES and TFA (Lencse 2004) can be found in (Lencse 2005).
If a subsystem seems to be too complex to be simulated in one model a further partitioning by expansion of the element can be considered.
Expanding a P element we may get a set of P and IT subsystems while an expanded IT may contain only IT subsystems representing a set of sub-functions of the element.
If we have a situation with more IT and P elements grouping or integrating elements may be appropriate.

SIMULATION META-METHODOLOGY SUPPORTING PARALLEL SIMULATION

The six-step process of simulation analysis method

In order to use in formulation of a meta-methodology, in the next point we describe a classic SM (Simulation Methodology).
SM is a six-step process comprising: (SM1) Defining goals (including preliminary design of models); (SM2) Gathering and analysing data; (SM3) Model design and model building (SM4) Performing simulation (with as-is, what-if analysis, model verification and validation); (SM5) Analysing simulation results; (SM6) Supporting implementation.
SM is also an iterative-type methodology which is applicable for both P and IT elements. In point SM1 we explicitly took into account a preliminary model design, which typically takes place only implicitly.
The decision about *parallel simulation* usually is made in step SM3 or SM4.

Outlining the meta-methodology with support for parallel simulation

Now we outline a meta-methodology (MM) applying the new concepts concerning conceptual models introduced in this paper, using the classic SSM together with SSM with modified conceptual models and SM described in previous point.

The phases MM1-MM4 basically follow the progress of SM but in MM2-MM3 there is a soft systems type progress also. In every phase classic SSM is applied if we are facing an unstructured problem and modified conceptual models are applied concerning questions of simulation.
Methodology steps based on our new concepts are listed in MM3.

The phases of meta-methodology are:

MM1. Goal definition

MM2. Identification of a widened set of relevant systems

MM3. Development of conceptual models containing systems to be simulated

- Identify P and IT subsystems, and elements to N&S conditions
- Define time relations in models, synchronise models, make time decomposition
- Define critical P and IT elements to be simulated
- Make decisions on partitioning and grouping of *P elements* for parallel simulation
- Make decisions on partitioning and grouping of *IT elements* for parallel simulation

MM4. Support for implementation

MM1 Phase of defining goals (SM1) has great importance: this is the basis for effectiveness and efficiency. Goals for simulation project should be got from the organisational goals and objectives by the way of goal partitioning and linking to the processes to be simulated. Soft method should be used for learning the situation and for defining requirements for simulation models.
Some fast full simulation cycles may be necessary to make clear the objectives. In this phase methods like TFA may be useful. Preliminary design of simulation models may be produced taking into account the principle of parsimony (Pied 1991).

MM2 In this phase a widened set of relevant systems is identified: (SM2) systems from where data should be get for simulation (to identify and analyse sources of data), systems for which simulation results may be interesting and systems probably to be simulated, that is all systems possibly influenced by the simulation project. During data analysis (SM2) typical and critical data configurations should be defined for the whole interval of simulation, or if possible for a longer time. Identification of typical and critical data configurations should be done for all relevant systems.

MM3 First, conceptual models to be simulated are selected and developed then the new methodological elements are applied.
In the selected models P and IT elements are identified by building up a map for the identified elements. Virtual time system is introduced into conceptual models and after selecting P and IT elements planned to be simulated precise time label values are assigned. Synchronisations of models are made through appropriate conditional elements. On the bases of synchronisation a decomposition of execution time of functions can be made. Now we may have a critical set of P and IT elements to be simulated.
Thinking in parallel simulation we make decisions about further partitioning or grouping elements: in case of too large subsystems we may try to use expansion for partitioning. The use of Statistical Synchronisation Method and TFA can be considered.
After making parallel-sequential decisions the traditional simulation is completed (SM3,4). At these points soft cycles may be necessary to define the what-if scenarios and also for verification and validation of simulation models.

MM4 Analysis of simulation results (SM5) may lead to going back to earlier points for further analysis and simulation or even if the results are satisfactory, the exact understanding may require more soft cycles.
Support for implementation of results (SM6) may consist of making correction plans. In making correction plans, further soft cycles and simulation may be useful.

CONCLUSIONS

We have developed new concepts to SSM to modify conceptual models:
- we have introduced a system of IT and P elements to help common analysis of ICT and BP systems taking into account N&S conditions of performing functions,
- we have defined the virtual time and conceptual model synchronisation concepts for compatibility with simulation methods,
- we have examined how the parallel simulation decision can be supported in conceptual model analysis.

Using the results in developing modified conceptual models we have outlined a meta-methodology dealing with unstructured problems in a simulation project and also supporting the application of parallel simulation.

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BIOGRAPHY

GÁBOR LENCSE received his M.Sc. in electrical engineering and computer systems at the Technical University of Budapest in 1994 and his Ph.D. in 2000. The area of his research is (parallel) discrete-event simulation methodology. He is interested in the acceleration of the simulation of communication systems. Since 1997, he works for the Széchenyi István University in Győr. He teaches computer networks and networking protocols. Now, he is an Associate Professor. He does R&D in the field of the simulation of communication systems for the Elassys Consulting Ltd. since 1998.
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