Developing a meta-methodology for efficient simulation of infocommunication systems and related processes

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The efficiency of simulation projects aimed at supporting the design of Information and Communication Technology (ICT) and related Business Process (BP) systems in an organisation is influenced by some key factors. The goal of the development of our simulation meta-methodology (MM) is to support the use of the most efficient method in any phase of the simulation process. In this paper we indentify the factors influencing the simulation problem contexts and making them dynamic, then we formulate the requirements on the MM determined by the dynamic simulation problem contexts taking into account the issue of efficiency and also that the simulation method itself is a hard-system method. On this basis we define the methodology set of MM that is a set of hard- and soft-system methods appropriate for different simulation problem contexts. We examine the important features of the MM methodology components, we describe the general features of the simulation methodology (SM) in detail, we propose and also define further requirements on SM determining extra features. We introduce the cycles and the process of MM including alternating way of work and the methodology chains which make MM suitable for dynamic simulation problem contexts.

1. Introduction

The efficiency of simulation projects aimed at supporting the design of ICT and related BP systems in an organisation is influenced by some key factors including also methodological factors. In our earlier papers we have already examined many of these factors and we also investigated the ways of increasing the efficiency [16-21].

It is important to note that in order to improve efficiency of simulation the MM under development focuses not only on the question of direct *efficiency* but also addresses the problems of the *efficacy* and *effectiveness* [9], either by means of first of all soft-system methods and preliminary modelling.

In this paper, first we outline the system focus of application of the meta-methodology and define the process of simulation. We use a new approach: the concept of *the dynamic simulation problem contexts.* We identify the factors influencing simulation problem contexts that is factors influencing simple-complex and unitary-pluralist features and making them dynamic are identified, which are also responsible for the existence of complex-pluralist problem contexts. On this basis we formulate the requirements on the new meta-methodology.

Then, we examine the set of elements of the simulation meta-methodology. As the starting point of formulation of SM, we examine the evolution of the traditional simulation methodologies. We introduce the general features of the proposed simulation methodology and also the new requirements on the SM which we define as special features of SM. We present a brief evaluation of the selection of both SSM (Soft Systems Methodology) and MCM (Modified Conceptual Modelling) methods. In the section about the further elements, we mention TFA (Traffic Flow Analysis) and EFA (Entity Flow-phase Analysis) methods which are proposed for rapid preliminary modelling, and we briefly describe meta-methodology element “goal reduction and linking”. We introduce important new elements: the *alternating way of work* of simulation meta-methodology and the *methodology chains* formed by the problem context sequences.

Then, the requirements, which are determined by the dynamic simulation problem contexts, on simulation meta-methodology (MM) are formulated from the point of view of efficiency, taking also into account, that simulation method itself is a hard-systems approach.

On this basis, a set of hard and soft systems methods for MM is defined, which is appropriate for different simulation problem contexts.

Important features of methodology elements of MM are introduced. These elements, which have already been described in our previous papers, are as follows: the typical synthesised Simulation Methodology (SM) with added special features, the Modified Conceptual Models (MCM) methodology, and other methods. The Soft Systems Methodology (SSM) is also presented as the basic soft-systems approach for MM.

The phases, the cycles, and the process of MM (including the alternating way of work and the methodology chains) – which make MM suitable for dynamic simulation problem contexts – are described.

Finally, the functioning of MM in a collaborative modelling environment is examined, which is a frequent situation.

2. Simulation and the environment of simulation

2.1 System Scope of the Simulation Meta-methodology

In this paper we develop a simulation meta-methodology appropriate for the examination of info-communication systems and connected processes.

The system scope of the simulation meta-methodology may be defined by the group of ICT (Information and Communications Technology) and related BP (Business Process) or OP (Organisational Process) systems. ICT and *connected* BP or OP systems form EIS (Enterprise Information Systems) or respectively OIS (Organisational Information Systems).

2.2 Process of Simulation

Definitions of simulation have been proposed by many authors (see for example [25]). Now, for the meta-methodology development purposes we propose the following approaches to the simulation:

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 results of simulation [15].

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.

2.3 Dynamic Simulation Problem Contexts

Modelling projects often start with an *unstructured problem situation:* even if there was a consensus about the application of simulation it may turn out in the "Defining Goals" phase that there is no agreement about the questions to be answered [22].

It is often necessary to use the simulation methodology in a soft-systems environment: even the problem structuring ("Defining Goals" phase) may lead to *complex-pluralist problem contexts for simulation* which require the application of a soft-systems approach but the *simulation is a hard-systems approach* appropriate for simple-unitary problem contexts (the problem contexts are described in [11], the features of hard-systems and soft-systems approaches can be found in [8]. Moreover, it is important to remark that the simulation problem context may change *dynamically* in any phase of the simulation process.

Now, we examine the factors influencing the *simulation problem context* according to the *simple-complex* and *unitary-pluralist* dimensions, which make problem contexts often complex-pluralist.

Factors influencing the simple-complex dimension:

- Systems are often only partially observable (for example data are not collected or cannot be collected because of technical reasons or because data sources are located in other systems).
- The systems of interest cannot be easily defined (for example, systems' boundaries are not observable because of data availability problems).
- Simulated systems are of probabilistic nature and may have active parts with independent objectives (for example people in the system may act in opposition to simulation project goals).
- The complexity may increase by taking into account the influences on other systems.

Factors influencing the unitary-pluralist dimension:

- Simulation project is performed in an environment formed by many participants:
  Decision makers, problem solvers (users, analysts, modellers, etc., who may also be decision makers in different phases), whose' views on the world influence the simulation problem context.
- The initial problem structuring often leads to a pluralist set of opinions regarding the goals [22].
- A disagreement can also occur regarding the implementation of results (for example, who is responsible for what during the implementation [22].

Simulation is an efficient method if it used as a hard-systems approach to the problems of simple-unitary contexts, therefore, to be efficient, we should have a *set of methods* appropriate for different contexts and we also should have a *formalised process, a simulation meta-methodology* to control the use of methodologies in dynamic simulation problem contexts.

3. Defining components of the simulation meta-methodology

The set of methods of the simulation methodology should contain a *traditional* simulation methodology (hard-systems method), a method appropriate for problem contexts requiring *soft-systems* approach and also a method *connecting* the hard-systems and soft-systems levels. It is also useful to have methods making the coverage of the simulation process complete supporting the improvement of the efficiency of simulation. In the following, we examine and introduce these elements of the set of methods.

3.1 Synthesis of a Traditional Simulation Methodology with Extra Features

Evaluation of Traditional Simulation Methodologies

The simulation method containing a series of phases has already been described by many authors [1-3,7,26]. These phases represent the highest level of development and application of the simulation model. This description level of the simulation process remains constant regardless of the type of the problem and the objective of the simulation analysis [7]. Furthermore, simulation models can capture the behaviour of both human and technical resources in the system [26]. Examining the methodologies described by the aforementioned authors, an *evolution* of methodologies may be observed, starting from the *problem-solution-type*, strictly hard approach to the present days' more *soft-approaches*.

The current state-of-the-art can be summarised according to the 3 main stages of methodologies:

Prior-to-modelling stage:

Simulation is project-based: it is a process with pre-defined objectives, which should be reached within a time and cost limit and with the required quality, using the resources assigned to the process. This view shows the collaborative character of a simulation project.

Modelling and experimentation stage:

For different tasks, there is a wide variety of simulation tools, with different model building and experimenting features, therefore methodologies can contain tool-specific features.

After-modelling stage:

Simulation becomes a decision support tool: the outputs of simulation can be regarded as *understanding-type results* supporting decision making rather than *solution-type results* providing an exact solution to a problem. The results of simulation are also *project-type results:* a report should be generated and documented for the defined participants of the project.

Typical Simulation Methodology

As an element of the simulation meta-methodology (MM) we describe a typical hard simulation methodology (SM) comprising six steps (the detailed description of SM is in [20]).

It is not a novel methodology, it is rather a *synthesis* based on the conclusions of the analysis described in the previous section, but we pay special attention to some requirements and define *extra features* for our typical SM.

The six-step process of simulation methodology (in *Figure 1*) has the following phases:

SM1: Defining Goals
SM2: Gathering and Analysing Data
SM3: Model Design and Model Building
SM4: Performing simulation
SM5: Analyzing Results
SM6: Supporting Implementation

Summary of Features of SM

Extra features:

- An *output is defined to each phase* in order to support methodological communication.
- Special attention is paid to *preliminary modelling*.
- Simulation is assigned to support implementation. Decisions in order to avoid disagreement about implementation (there are often different views on implementation of results).

General features:

- SM is a tool-independent methodology.
- SM puts equal emphasis on each of the three main phases.

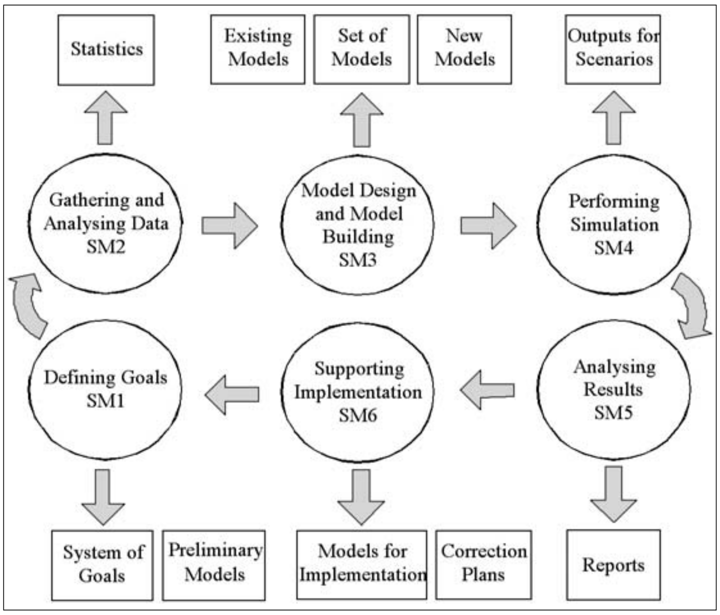

Figure 1. The six-step process of simulation methodology with extra features

- SM can be applied to simulate both BP and ICT elements of an organisational information system.
- SM, like all the examined methodologies, has an *iterative* character, phases or group of the phases can be repeated until they produce a suitable outcome.
- SM has a *cyclic* character, that is, the methodological loop may be closed forming short-cycles or long-cycles:
  - There can be any full or partial methodological cycles during a simulation project (short-cycles)
  - The simulation models may be reused at any point of time, later, during the life-cycle of the modelled system (long-cycles)

3.2 SSM in the Simulation Meta-Methodology: Short Evaluation of SSM and other Possibilities

SSM is the classic soft-systems approach [8]. Arguments for selecting SSM as MM element may be summarised as follows:

The methodology should be able to face with soft-problem situations both in ICT and BP fields.

The well known approach of UML has the capabilities to face with ICT and BP sides but UML is weak in dealing soft aspects [6]. TSI (Total System Intervention [12]) is rather a framework of methodologies (with a large set of associated methodologies) and there is no known experience of using it in ICT or BP field. For SSM there is a significant amount of applications and experience to use it with or in other methods [10,5].

3.3 MCM in the Simulation Meta-Methodology: Short Evaluation of MCM and other Possibilities

By simulation the dynamic features of systems are investigated, therefore it is necessary to use time in simulation models.

The introduction of time into UML is described in [24], but UML is weak in dealing soft situations as we have already seen. Gregory's method [13, 17] is a method based on SSM and operates with "enhanced" conceptual models but it has no appropriate time tools (synchronisation of model times, time decomposition) which are necessary in a simulation environment and does not differentiate between IT and P systems which is also necessary for efficient simulation.

Usual approaches to use SSM models together with other methods include grafting and embedding [23]. (Examples for grafting and embedding can be found in [4] and [5], respectively).

MCM (SSM with modified conceptual models) may be characterised as an *extension* of SSM models with *extra features* and grafting the methods of using extended models into SSM. This way MCM is applicable both at soft-system and hard-system level, supporting the elimination of the *methodological gap*.

3.4 Further Components

Further elements are the TFA (Traffic Flow Analysis) [17,18] and EFA (Entity Flow-phase Analysis) [16-18] which are methods for rapid preliminary modelling and for goal reduction and linking.

An enterprise has a set of goals with formal and informal features. The goals in a current set of goals influence each other and may also be in conflict with each other [14]. Goals of the simulation project should be obtained from higher level goals. The *"SSM problem learning"* method and the *"goal-reduction-linking"* method support the goal setting process of the simulation project.

4. Cycles and working process

4.1 Cycles of the Simulation Meta-methodology

The detailed description of elements, outputs and phases of MM is given in [19] and [20].

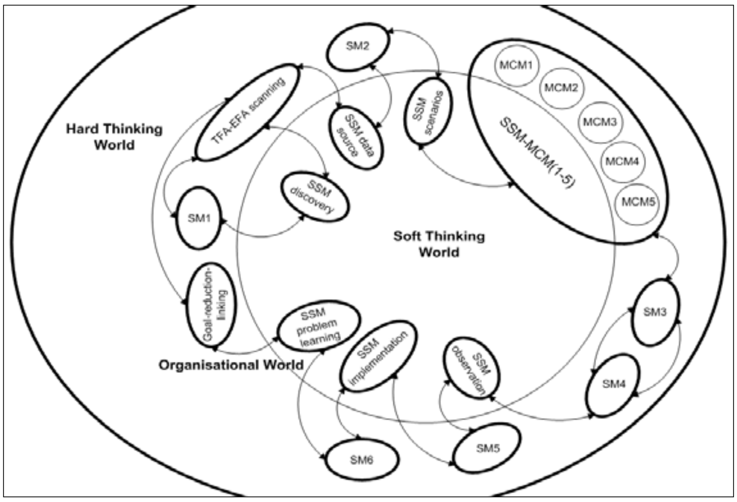

Figure 3.
The alternating way of work of the simulation meta-methodology

The main methodological cycle of MM is the MM1-MM4 cycle (indicated by empty arrows in *Fig. 2*). The progress in the main cycle occurs according to SM1-SM6 steps. In an MM phase there can be usual sub-cycles indicated by dashed lines and arrows. Preliminary modelling may be connected to MM1 or MM2 too and may induce sub-cycles between MM1 and MM2 phases. MCM cycle is shown by dashed lines and an arrow in MM3. It may form its own sub-cycle inside the phase. (A possible sequence of cycles is demonstrated in *Fig. 3*.)

4.2 Working Process of the Simulation Meta-Methodology

In order to be efficient and to be able to address the dynamic problem contexts of simulation we should have a *full and compatible set of methods* covering the whole process of simulation. (This set of methods is introduced in the sections about SM, SSM, MCM and in the "Further Components" section.)

The meta-methodology *governs* the use of the methods during the process of simulation: the meta-methodology supports the use of the suitable method for every situation (simulation problem context) or from other point of view it *directs* the work in the dynamically changing contexts taking into account that the simulation itself is a hard-system method.

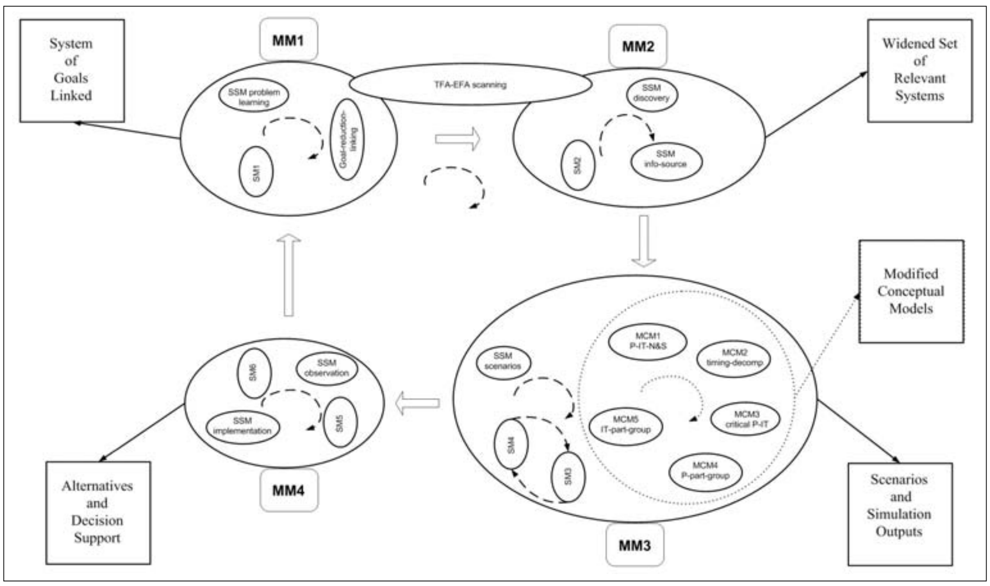

Figure 2.
Elements and cycles of the simulation meta-methodology

In the process of performing simulation (simulation project) usually *dynamic simulation problem contexts* occur.

Therefore MM should have the possibility to "soften up" the methodology and then, after exploring the problem context, to "harden up" again. The *alternating hardening and softening up* the methodology means that after hard cycles (which are directed to find a solution in a given step) it is necessary (or advisable) to use soft cycles, in order to explore the whole situation.

The sequence of hard and soft methods in the process of using the meta-methodology forms a *methodology chain:* in the chain each of the elements (methods) uses the results of the previous element and prepares the use of the next element. The methodology chain is started and finished by a soft method application. The methodology chain may be described by the sequence of simulation problem contexts and by the methods used to the contexts.

Figure 3 shows that Organisational World is divided into two segments: the Hard Thinking World and the Soft Thinking World. Soft-systems methods are situated in the Soft Thinking World and hard-systems methods are in the Hard Thinking World. MCM operates between these two segments. MCM process starts and finishes its operation with the "SSM problem learning" method.

Different methods are connected by a bi-directional connection which indicates that in the process of MM if it is necessary we may re-enter an earlier step. A sequence of steps performed according to connections shows the alternating work of MM. (Of course in the process of operation of MM it may be necessary to use other connections (which are not shown in the figure) between methods.)

5. Summary

In this paper, we presented the further development of the new simulation meta-methodology. Our main goal was to increase the efficiency of simulation by supporting the use of the most efficient method for a given problem context (simulation problem context) in any phase of the simulation process by means of the meta-methodology.

For our examination, we have defined the system scope of the simulation meta-methodology (systems for which we intend to apply the simulation meta-methodology) and we have also defined the process of simulation we used in our considerations.

The factors influencing simulation problem contexts and making them dynamic have been identified.

The requirements on MM determined by the dynamic simulation problem contexts have been described taking into account the point of view of efficiency and also the hard-systems character of the simulation method itself. A set of hard and soft systems methods (appropriate for different simulation problem contexts) for MM has been defined and the most important features of methodology elements of MM have been introduced.

We have given a short overview of the elements of the methodology set of MM, described the general and special features of the typical, synthesised SM and the cycles and the working process of MM (including the alternating way of work appropriate for dynamic simulation problem contexts and the methodology chains).

The important aspects of this paper may be summarised as follows: a complex approach to the efficiency issue of simulation is described (taking into account the whole process of simulation including modelling); on this basis the first formulation of general requirements to the problem is introduced; by developing the simulation meta-methodology (and its methodology elements), an efficient answer to the problem is proposed.

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