THE ROLE OF KNOWLEDGE THROUGHOUT THE SIMULATION LIFECYCLE: WHAT DOES A SIMULATION MODEL KNOW?

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Abstract

A simulation model is more than just a tool necessary to achieve certain objectives of experimentation and cognition. In the course of a simulation project the simulation model is developed, modified, used, evaluated and extended within an ongoing process. Therefore, it is also a kind of dynamic repository containing knowledge about parameters, causal relations and decision rules gathered through purposeful experiments. In the end, knowledge stored in the simulation model can be considered proven, independently of whether it was developed by the domain expert him- or herself or by a consultant simulation expert. Unfortunately, this knowledge is usually not very well documented and therefore does exist implicitly only inside the simulation model. To be used when the results of the simulation project are put into practice, it needs to be explained in such a way as to be accessible to the domain expert in the subject-specific terminology and to be applicable without any loss of information or misrepresentation. Against this background the paper proposes a formalizable documentation framework (in terms of both structure and procedure), specifies a detailed, but consistent sub-structuring of relevant simulation knowledge categories, and analyzes which simulation knowledge precisely comes in which form and way from where, which knowledge is implicitly represented by the simulation model and how a particular component-based simulation package allows access to it.

Keywords: knowledge-based simulation, simulation knowledge, knowledge management, discrete event simulation.

Presenting Author's biography

Gaby Neumann received a PhD in Logistics from the University of Magdeburg. Since 2003 she has been Junior Professor in Logistics Knowledge Management there. She also has been part-time consultant in logistics simulation since 1991. Her current activities and research interests are mainly linked to fields like problem solving and knowledge management in logistics, logistics simulation and planning, but cover also technology-based logistics learning, didactics of teaching logistics as well as logistics competence profiling and assessment. She has widely published in these fields and has been or is being involved in a couple of respective projects. Her e-mail address is gaby.neumann@ovgu.de.

1 Introduction

Often modeling and implementation are quite superficially aimed at running simulation experiments and case studies. Here, the simulation model is just a tool necessary to achieve certain objectives of experimentation and cognition. This understanding is undoubtedly right, but covers only one side of the potential offered by a simulation project. If one considers the whole picture, the simulation model is more than an executable reproduction of the real or planned logistics world to be analyzed. In the course of a simulation project a series of models is being built to represent the object of investigation in different ways [1]: The conceptual model informally (textually or graphically) specifies the simulation problem, its objects and their behavior, data structures etc. The formalized model applies a particular modeling paradigm for formal specification of simulation objects (i.e. data types, functions). Finally, the (executable) computer model allows dynamic experimentation for problem solving. Each of these models forms a specific milestone in the simulation lifecycle representing not only the problem and its components, but also the current state of knowledge about its solution. Thus, the simulation model is developed, modified, used, evaluated and extended within an ongoing process. Therefore, the simulation model is also a kind of dynamic repository containing knowledge about parameters, causal relations and decision rules gathered through purposeful experiments. In the end, knowledge stored in the simulation model can be considered proven, independently of whether it was developed by the domain expert him- or herself or by a consultant simulation expert [2]. Usually this knowledge is not very well documented and therefore exists implicitly only inside the simulation model. To be used when the results of the simulation project are put into practice, it needs to be explained in such a way as to be accessible to the simulation customer as domain expert (e.g. in the field of logistics) in the subject-specific terminology and to be applicable without any loss of information or misrepresentation. Otherwise the technical or organizational solution in the real world cannot be expected to work in the way demonstrated by the respective simulation model.

To this day the translation of simulation knowledge into the domain expert's terminology or even directly into the source code of, for example, a control system or a control station remains an unsolved problem. Thus one continues to find a break and discontinuity in applying simulation results. Knowledge important for the realization of simulated functionality is lost and needs to be re-developed by renewed implementation and testing. Although literature has described modeling and simulation as both, knowledge-processing activity and goal-directed knowledge-generation activity [3], the term 'knowledge-based simulation' is typically used for applying AI approaches to automatically create simulation models from expert knowledge. The fact that non-formalized expert knowledge finds its way into the simulation model on one hand or is created throughout the simulation lifecycle and needs to be externalized on the other is not in the focus of research in this field. That is why, information about decisions taken when building the model or running experiments as well as really new knowledge about the particular application or even about the simulation methodology gained in the course of a simulation project quite often stays in the heads of the people involved in the project. Even project report and presentations contain selected, focused parts of this knowledge, only.

To overcome this unpleasant situation consistent, up-to-date knowledge about the simulation model and its developmental process needs to be gathered directly from and continuously during the simulation project. To achieve this, all participants in a logistics simulation project, i.e. simulation experts and logistics experts, need to be encouraged (and supported) permanently to provide background knowledge about his or her motivation for going in one rather than the other direction, for changing the model structure or parameters in a certain way, for keeping a particular type of possible solution and abandoning others, for looking for information, knowledge and support from one source instead of another. This procedure will only work if directly integrated into the "normal" simulation activities – with no or little extra effort. Techniques like structured documentation, continuous exchange or ongoing reflection and generalization help to cope with this and to master complexity and dynamics to the benefit of both a certain simulation project in particular and simulation methodology in general.

This helps to identify who knows what about the logistics system and process, but also about the simulation project behind it, why something was decided in which way, which system configuration and which set of parameters worked how well together, what is represented in the simulation model and what are the limitations of its validity and usability. With this the process of a simulation project becomes a process of knowledge creation and acquisition at the same time without too much additional effort for all involved. As pre-condition, the documentation task needs to be embedded into the "ordinary" problem-solving activities as seamlessly as possible. For this, comfortable interfaces and links to the simulation tools need to be developed or an extended functionality for commenting and annotation is directly to be integrated into them. Ideally, the main part of the project knowledge to be documented is directly (and in this way hidden to the persons involved in the simulation project) taken from documents and models which are produced in the project anyway as well as from tools which are commonly used for experimentation purposes or statistical analysis of simulation outcomes.

2 Logistics simulation knowledge

Knowledge is generally defined as reasoning about information and data to actively enable performance, problem-solving, decision-making, learning, and teaching [3]. In logistics simulation as in any other kind of problem-solving this knowledge is to be related to both the subject of the simulation study and the procedure of the simulation project. In general, logistics simulation knowledge can be described as entirety of specific or generalized theoretical or experienced knowledge about the simulation problem and its solution (subject-related knowledge), but also about the procedure and organization of the simulation project (procedure-related knowledge) that either explicitly or implicitly exists or is created in the course of the simulation project [4].

In particular, subject-related logistics simulation knowledge (see Fig. 1) comprises:

1. Domain-specific knowledge necessary to clearly understand specifics and constraints of the application area. In our case this refers to general knowledge about logistics and material flows on one hand and complementary knowledge from related fields on the other.
2. Problem-specific knowledge unambiguously characterizing the specific problem to be solved in this particular simulation project. In logistics simulation this includes knowledge about the logistics system and process to be investigated, logistics objects affected by them and links to the system's environment to be taken into consideration, but also knowledge about the question, goals and constraints of the simulation.
3. Solution-specific knowledge describing the outcomes of the simulation project. This covers all knowledge explaining how the given or identified problem might be solved. Depending on the current stage of the problem-solving process and phase of the simulation project it consists in two ways. Hypotheses on how a possible solution to the given problem might look like can refer to an appropriate system/process design, resulting system behavior, maximum system performance or any other target characteristics of relevance. Output data or results in the form of system characteristics (e.g. performance indicators) and recommended designs or modifications of a planned or existing logistics system and process evolve in the course of the simulation project to answer all questions directed to the simulation.

In contrast, procedure-related logistics simulation knowledge (see Fig. 1) includes:

1. Methodological knowledge necessary to run a logistics simulation project. This refers to simulation knowledge, but also to underlying concepts from problem-solving and decision-making etc.
2. Management knowledge covering all aspects of the strategic and operative management of a simulation project.

Thus, logistics simulation knowledge combines aspects from a wide variety of subjects and logistics simulation projects require a respective collection of interdisciplinary expertise. Furthermore, logistics simulation knowledge is dynamic and always evolves in the course of a project.

3 Knowledge sources in logistics simulation projects

Correspondingly, there are numerous and diverse sources and holders of logistics simulation knowledge.

3.1 Simulation project input and output

Input information to a simulation project usually come with the tender specification for the simulation project or are to be identified and generated in the problem definition and data collection phases of the simulation (Fig. 2). Procedure-related knowledge and even more solution-specific knowledge are represented in the "products" of the simulation project. The simulation model, for example, is not just a tool for experimentation but also a kind of a dynamic repository containing knowledge about parameters, causal relations and decision rules gathered through purposeful experiments. Unfortunately, this knowledge is not very well documented and therefore exists implicitly only inside the simulation model. Thus one continues to find a break and discontinuity in applying simulation results. Knowledge important for the realization of simulated functionality is lost and needs to be re-developed by renewed implementation and testing. Even project report and presentations contain selected, focused parts of this knowledge, only.

3.2 Simulation knowledge stakeholders

As in any other field, simulation projects in the field of logistics are organized in the form of a service involving both, simulation experts and logistics experts with individual knowledge to be of use at certain stages in the project [5]: at the beginning of the simulation project only the logistics expert specifically knows the processes and their problems. Unfortunately, this knowledge is mainly of an internal nature (existing inside the brains and experience of people directly involved) and is externalized very poorly in any kind of document or file. For this reason, additional time and patience are spent by the logistics expert on the explanation of what the simulation model should reproduce. The simulation expert inevitably has to work on his or her own understanding of the situation and problem right from the beginning by using techniques for systematic analysis and abstraction. This newly created knowledge on the part of the simulation expert needs to be matched against that of the logistics expert or even against reality for the purposes of validation and evaluation. In this way, knowledge is created at an initial level that could have been acquired much more easily from the knowledge sources of the customer organization if known and accessible.

Furthermore, the model-building process should be seen as an important phase of collecting, evaluating and structuring information. With this, really new knowledge is accordingly created with both the logistics expert and the simulation expert. The logistics expert learns about the methodology, steps and tools of simulation; the simulation expert gains enhanced knowledge and experience of the application area and its specific problems from the joint developmental process. However, for these achievements to be lastingly effective, both the knowledge itself and the process of knowledge-creation and exchange need to be described, recorded and stored in well-structured documents which are easily understood and open to purposeful access by future logistics or simulation experts.

4 Structured documentation as key to simulation knowledge

Summarizing the current state-of-research with regard to supporting knowledge explication in simulation projects in general [6], [7], [8] and in logistics simulation projects in particular, it can be stated that the research questions as mentioned earlier are not answered yet. Furthermore, technical implementation remains difficult; already implemented functionality is scattered across various existing software solutions. Approaches to document methodological simulation knowledge, a comprehensive approach for seamlessly integrating respective functionality into the simulation tool as well as a formalized documentation structure are still missing.

The proposal for how such a formalizable documentation framework (in terms of both, structure and procedure) might look like is presented in Fig. 3. Here, a simulation project meeting is used as example for specifying knowledge and input to be documented: apart from categories with typical information on a meeting, such as location, time, participants etc., this framework allows collecting detailed knowledge about the particular simulation project. For the latter, subject-related knowledge was clearly separated from procedure-related knowledge and individual sub-categories for both knowledge aspects have been defined. Following the basic structure of a viewpoint description each knowledge category contains documentation and criticism parts. Whereas the documentation part of procedure-related knowledge represents the main aspects of a simulation-based problem-solving process in general, the documentation part of the subject-related knowledge was specifically structured according to the application area of logistics. Consequently, on the first level it is further divided into object, system, process and environment categories which are suitable to completely describe a logistics or supply chain problem and solution. If the proposed documentation framework is to be applied to any other application area of simulation, this specific part would have to be adapted to the relevant elements of problems and their solutions in this particular area.

If in each project meeting one copy of this template is filled with the particular contents and results, a growing set of documents with structured simulation knowledge is produced. In addition to this, further documents, written or oral communication outside the meetings and further external knowledge sources used within the project can be analyzed in a similar way and thus increase the project-specific knowledge collection. From composing all of these individual documents step-by-step and according to project progress, a project-accompanying structured documentation of both the state-of-the-problem (and solution) and the state-of-the-problem-solving (including the state-of-development of the simulation model, methods and tools used or decisions taken) is derived.

At the same time the state-of-documentation resulting from each newly added source of knowledge also represents the particular state the project had reached at that point in time. With this, not only moment-specific representations of project knowledge, but also period-related representations of project progress become storable in a formalized way. Due to the fact that knowledge on the problem or solution and knowledge on the project procedure are always jointly documented, not only a purposeful reflection of taken decisions is required, but also a clear explanation of all modifications to the model, procedure or solution initiated by those decisions. Together with the corresponding files containing the simulation model this would principally allow to return to any point in the problem-solving process and continue from there towards a different path whenever this seems to be necessary or appropriate.

In principle, application of this approach for a structured documentation might offer a number of chances:

- To support an ongoing communication between the partners in a simulation project for achieving a common understanding of the logistics process and system to be investigated;
- To avoid any loss of information and knowledge in the course of the simulation project;
- To provide a kind of check list for data collection and a template for model design straight at the start of the project (What is to be taken into consideration for model building? Which information are required for the investigation?);
- To integratively develop and continuously complete a comprehensive description of the simulation model with regard to its structural,

parametric and functional design as well as concerning modeling approaches and internal model attributes which might be relevant for its eventual reuse.

- To (automatically) create the draft of the simulation project report directly from the ongoing project documentation (including all assumptions, agreements, decisions).

5 References

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ISBN 978-3-901608-32-2