HOW TO BENEFIT MORE FROM INUITIVE POWER AND EXPERIENCE OF THE HUMAN SIMULATION KNOWLEDGE STAKEHOLDER

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ABSTRACT

Generally, it is pretty clear and widely accepted that the human actor plays a significant role in any simulation project – although in recent years some authors proclaimed a revival of human-free simulation at least related to distinct parts of a simulation study. Therefore, the paper aims to provide an overview on needs and challenges in model-user interaction as well as on approaches, methods and tools to support the user in bringing in his/her knowledge in all phases of a simulation project from model building via understanding a model and using it for experimentation to correctly interpreting simulation outcome. Furthermore, barriers and problems hindering a simulation stakeholder in sharing his/her knowledge are identified and approaches to access and extract such knowledge are discussed in order to avoid inefficiency and failure in future projects.

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

1. INTRODUCTION AND MOTIVATION

The impact of a person's knowledge and background on the design, level-of-detail and focus of the simulation model, i.e. on the way a simulation model appears and functions, was demonstrated, for example, by Neumann and Page (2006). Here, two groups of students with different background (computing vs. logistics) but the same level of simulation knowledge and experience were assigned with the same problem to be investigated. In the end both student projects produced valid and usable simulation models, but efforts for model implementation, model modification in the course of experimentation and visualization of results were quite different. Results achieved from either model equally allowed responding to the initial questions addressed to the simulation project; from this it was possible to conclude that despite of different modeling approaches simulation results are comparable and of similar quality. This way, the case study gave proof of the fact that different persons with different background might produce different but in the same way correct and usable simulation models of the same problem and situation just because of their individual knowledge and experience. Consequently, the individual background significantly impacts the whole range of a simulation project from model building till interpretation of results (see Figure 1).

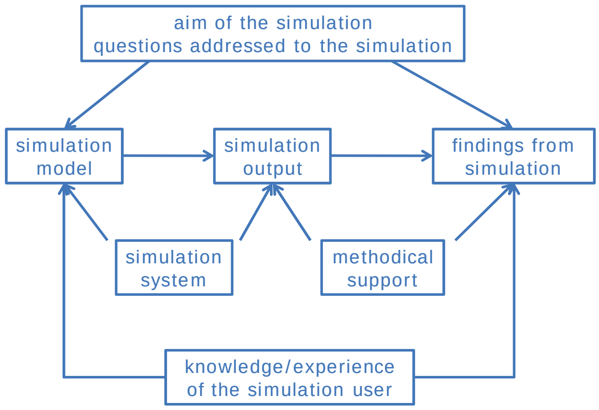

Figure 1: Impact of the simulation user on the outcome of a simulation project

Neumann and Ziems (1997) went into detail with identifying human simulation knowledge stakeholders' impact on certain simulation project stages. According to this, simulation experts are primarily responsible for model building and implementation steps, whereas domain experts mainly provide application-specific knowledge for problem description, identification of input data and evaluation of results. This corresponds to the type of knowledge and experience brought into a simulation project and gained from a simulation project by the different actors. Therefore, simulation needs to be understood in its entire characterization as complex problem-solving, knowledge-generation and learning process at the same time.

This view is in line with literature characterizing modeling and simulation in general as both, knowledge-processing activity and goal-directed knowledge-generation activity (Ören 1990). Based upon this, advanced methodologists and technologists were expected to be allowed to integrate simulation with several other knowledge techniques. But looking at today's situation in simulation projects it still has to be considered that a sound application of a knowledge management perspective to modeling and simulation is still missing. Instead, the term 'knowledge-based simulation' is typically used for applying AI approaches to automatically create simulation models from expert knowledge. Research focuses, for example, on developing efficient and robust models and formats to capture, represent and organize the knowledge for developing conceptual simulation models that can be generalized and interfaced with different applications and implementation tools (Zhou, Son and Chen 2004). Other work aims to develop concepts for modeling human decisions, e. g. in manufacturing systems (Zülch 2006), or to model and simulate human behavior to support workplace design by use of digital human models (Monteil et al. 2010) and especially by incorporating human characteristics like fear, aggressiveness, fatigue and stress in particularly challenging situations (Bruzzone et al. 2010).

In contrast to this, 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. Furthermore, the simulation model itself also forms a kind of dynamic repository containing knowledge about parameters, causal relations and decision rules gathered through purposeful experiments. This knowledge is being somewhat hidden as long as not being discovered, understood and interpreted by another person.

Against this background, research on implementing a knowledge management perspective in simulation projects should address the following questions:

- Which information and knowledge is needed by whom at what stage of a simulation project?
- Which knowledge and information is provided by whom in which step of a simulation project?
- Which knowledge is generated with whom in which step of the simulation project?
- Which knowledge is "stored" in the conceptual and simulation models, evolves from simulation experiments, and is "hidden" in the input/output data of simulation runs?
- How simulation knowledge with the different stakeholders or repositories can be accessed, extracted, externalized and distributed, shared, applied?

To generalize research needs, the biggest challenge for properly handling modeling and simulation knowledge by applying knowledge management methods and tools consists in providing the right knowledge of the right quality and with the right costs at the right place and time. In other words, it is essential not to focus on the introduction of knowledge management technology and integration of software tools for storing and retrieving knowledge and information only, but to put the human resources running model building and simulation projects into the centre of gravity and to try to give them that kind and amount of support which is needed in a particular situation.

Therefore, the paper aims to provide an overview on needs and challenges in model-user interaction (Section 2) as well as approaches, methods and tools to support the user in bringing in his/her knowledge in all phases of a simulation project from model building via understanding a model and using it for experimentation to correctly interpreting simulation outcome (Section 3). Barriers and problems hindering a simulation stakeholder in sharing his/her knowledge are identified and approaches to access and extract such knowledge are discussed (Section 4). Findings are summarized and conclusions are drawn in Section 5.

2. NEEDS AND CHALLENGES IN MODEL-USER INTERACTION

Once a valid simulation model is available it serves as tool for different types of studies:

- In a *what-if analysis* the user discovers how a system reacts on changing conditions or performance requirements, i.e. system loads. During experimentation a particular type of changes is introduced to the model in a systematic way in order to understand sensitivity of a certain parameter, design or strategy.
- A *what-to-do-to-achieve investigation* aims to answer questions like how to set system parameters or how to improve process control in order to reach a certain behavior or performance level. Experimentation might be multidimensional including different types of changes to the model; it is strongly oriented towards identifying modification strategies for reaching a particular performance objective or target behavior.
- *Performance optimization experiments* serve to solve a particular target function such as minimizing job orders' time in system or stock level, maximizing service level or resources' utilization, etc. Here, the limits of typical performance characteristics are to be identified with the respective limit value itself forming the goal of the investigation.

No matter which type of investigation is on the agenda the user always needs to interact with the model in order to implement the intended experimentation strategy and to gain simulation results.

Interaction prior to the simulation run (or a batch of simulation runs) might consist in adjusting the structure of the simulation model, in purposefully changing one or more model or simulation parameters, or even simply in starting the simulation in order to produce and collect simulation output data that are expected to be of use for the investigation. Post-run interaction focuses on accessing and dealing with simulation output data in the form of dynamic visualization (i.e. watching animations) or statistical analysis (i.e. checking original or condensed data, viewing diagrams or other types of graphical representation) in order to achieve findings with regard to the focus and aim of the investigation. Consequently, the entire interaction cycle can be characterized as a user-model dialogue: any pre-run interaction with the model corresponds to the concept of asking questions; post-run interaction is adequate to the concept of responding to questions. Pre-condition for a successful user-model dialogue is true understanding in both directions. The simulation model needs to “understand” what the user is interested in and looking for. This requires the ability to ask the right questions from the user. Those questions might either be very specific and clearly matching “the language of the model” (i.e. directly addressing input/output data of a simulation) or they are of more principle, general, eventually even fuzzy nature requiring a kind of translation for being understandable to the model. When it comes to the responding part of the dialogue the user needs to understand the simulation output for getting the answers s/he was looking for.

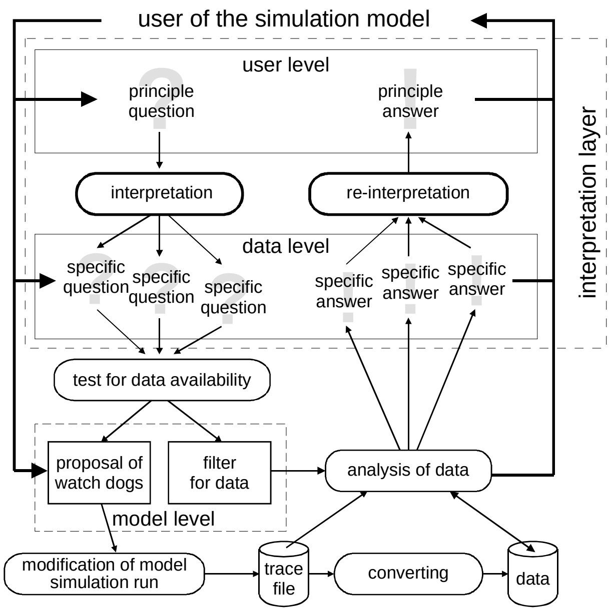

Figure 2: User-data interaction for simulation output analysis

When the potential interests a simulation user might have in a simulation study are compared, one significant difference emerges: specific questions formulated by the user might directly be answered with concrete simulation output at data level; those usually fuzzy questions of principle from the more global user’s point of view require interpretation and re-interpretation steps before being answered. Here, any question of principle has to be transferred to the data level by explaining it in detail and putting it in terms of concrete data (see Figure 2). As result of this process of interpretation a set of specific questions is defined with each of them providing a specific part of the overall answer in which the user is interested. Questions at data level correspond to results that can be delivered directly by the simulation even if minor modifications to the simulation model should be required (Tolujew 1997). This is the kind of study also current approaches for automatic trace file analysis in order to better cope with large amounts of simulation output data support (Kemper and Tepper 2009, Wustmann et al. 2009). Those approaches mainly focus on formalizing simulation outcome in the context of a certain application area. With this they remain at data level, whereas deriving answers of principle to questions of principle requires processing further the respective set of specific answers. These steps of additional analysis and condensing can be understood as a process of re-interpretation to transfer results from data to user level.

All steps of interpretation and re-interpretation aim to link the user’s point of view to that of the simulation model. They not only require an appropriate procedure, but, even more importantly, an interpretative model representing the application area in which simulation takes place. This model needs to be based on knowledge and rules expressed in the user’s individual expertise, but also in generalized knowledge of the problem environment regarding design constraints or system behavior and the experience of the model building expert derived from prior simulations. This knowledge might not only be of explicit nature, i.e. existing independent of a person and suitable to be articulated, codified, stored, and accessed by other persons, but also comprises implicit or tacit knowledge carried by a person in his or her mind often not being aware of it. Whereas explicit knowledge might be transferred into rules and algorithms, tacit knowledge cannot be separated from its owner and therefore requires direct involvement of the knowledge holder in the interpretation process.

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 (Neumann and Ziems 1997). 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. Otherwise the technical or organizational solution in the real world cannot be expected to work in the way demonstrated by the respective simulation model or knowledge important for the realization of simulated functionality needs to be re-developed by renewed implementation and testing.

3. METHODS AND TOOLS FOR BRINGING IN SIMULATION KNOWLEDGE

Human resources involved in a simulation project are the key factors for its success and efficiency. As discussed in the previous section it is always up to the simulation user to define objectives of any simulation and target functions of any experimentation. For this detailed knowledge and understanding on the particular system/process to be investigated and problem to be solved is needed as well as sound background knowledge on the domain and experiences in simulation-based problem solving. As this individual knowledge and experience belongs to the person carrying it and continuously develops and grows over time with each new simulation project, it can be separated from the person, i.e. externalized, to some extent only. Therefore, a mix of methods and tools for bringing in a user's knowledge and experience into the simulation project is needed:

- Formalize what can be formalized and incorporate this into simulation tools completed by a rule-based supporting system and an interface for its continuous improvement.
- Apply algorithms to routine problem-solving (Kemper and Tepper 2009, Wustmann et al. 2009).
- Enable a structured dialogue between the user and the tool by applying the concept of oracle-based simulation model validation (Helms and Strothotte 1992).
- Provide support in structured documentation of problem, model, experiments, solution/findings and lessons learned (Neumann 2006).
- Use human intuition and tacit knowledge for all that cannot be formalized (yet).
- Allow the user to bring in his/her ability of flexible thinking for problems and questions that unexpectedly pop-up in the course of a simulation study (Tolujew et al. 2007).

Here, it is crucial to initiate an ongoing learning and improvement process as basis of structured knowledge explication and gathering of experiences similar to what has been proposed by Brandt et al. (2001) for software engineering projects. Applying this approach to learning from simulation projects, a well-defined and well-structured documentation of both simulation model and simulation runs and the simulation project with all its assumptions, agreements, and decisions has to be established (seamlessly and continuously). Procedures help to identify who knows what about the 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 work well together, what is in the simulation model and what the limitations of its validity and usability are. 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 (see Figure 3).

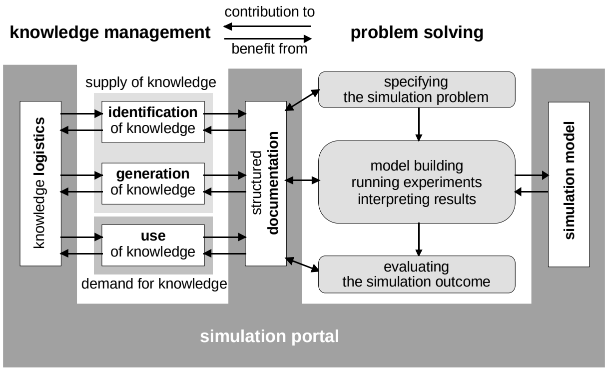

Figure 3: Problem solving and knowledge acquisition in the course of a simulation project

The clue to the successful implementation of those knowledge management procedures is often an appropriate (supporting) environment and climate in the organization. Concerning this, there is a greater need for a cultural shift than for additional software tools and IT solutions. Adopting a statement on human needs for computer technology by Shneiderman (2002) the link between knowledge management and (simulation-based) problem solving can generally be described as follows: the old discussion about how to support problem solving is about what (software) tools can do; the new discussion about how to support problem solving is (and must be) about what kind of problem-solving support people really need.

4. PROBLEMS AND BARRIERS IN SIMULATION KNOWLEDGE SHARING

In the course of a simulation project there are bidirectional links between activities for problem solving and knowledge management. On one hand knowledge available with persons, inside organizations and in the form of technology is (re-)used to build a model, plan and run experiments, analyze and understand simulation output. On the other hand knowledge about the problem's final solution and the chosen mode of action for its generation characterizes the increased scientific basis and additional experience of the problem-solving person, team or organization. Usually these links are based upon the persons directly involved in the simulation project. It's quite common to make use of own experience, but to benefit from knowledge, experience and lessons learned from other parts of the organization that is still not the usual procedure yet. To overcome this and to make knowledge of a successful or even unsuccessful problem solving process available to future simulation projects that is the challenge for knowledge management and its integration into personalized problem solving.

Being aware of this, organizations invest a large amount of money in technology to better leverage information, but often the deeper knowledge and expertise that exists within the organization remains untapped. The sharing of knowledge remains limited in most respects, and at least, strained. APQC (2004) sees major reasons for this in technology that is too complicated and the human nature that poses barriers to knowledge sharing. Cultural aspects can enhance an open knowledge transfer or inhibit a positive attitude towards knowledge sharing. Taking cultural aspects into consideration requires letting the knowledge management approach – and with this the knowledge sharing process in particular – fit the culture, instead of making an organization's culture fitting the knowledge management approach (McDermott and O'Dell 2000).

In a perfect world the benefits of accessing and contributing knowledge would be intrinsic: people who share knowledge are better able to achieve their work objectives, can do their jobs more quickly and thoroughly, and receive recognition from their peers and mentors as key contributors and experts. Nevertheless, knowledge is often not shared. O'Dell and Grayson (1998) identified four common reasons for this:

- *Ignorance*. Those who have knowledge don't realize others may find it useful and at the same time someone who could benefit from the knowledge may not know another person in the company already has it.
- *No absorptive capacity*. Many times, an employee lacks the money, time, and management resources to seek out information they need.
- *Lack of pre-existing relationship*. People often absorb knowledge from other people they know, respect, and like. If two managers don't know each other, they are less likely to incorporate each other's experiences into their own work.
- *Lack of motivation*. People do not see a clear business reason for pursuing the transfer of knowledge.

To meet these challenges, the discipline of knowledge sharing should continuously be reinforced. For this, there are two different approaches: the organization might host visible knowledge-sharing events to reward people directly for contributing to knowledge or the organization might rely on the link between knowledge sharing and everyday work processes by embedding knowledge sharing into "routine" work processes. Here, initiating of a close, interpersonal link between a mentor or coach (the expert) and the novice is a promising way not to rely on enthusiasm only, but to bring in a personal commitment to the process of developing another person's simulation competence.

Those expert-novice links might also be part of learning processes to improve an individual's simulation competence in a learning-by-doing scenario. The pedagogical framework for this is formulated by the cognitive apprenticeship theory (see Collins et al. 1989): in general an apprentice is a learner who is coached by a master to perform a specific task. Based on this, the theory transfers the traditional apprenticeship model as known from crafts, trade and industry to the cognitive domain. More precise, cognitive apprenticeship aims at externalizing processes that are usually carried out internally. This approach works with methods like modeling, coaching, scaffolding, articulation, reflection and exploration. Coaching, for example, is to be understood as helping a person in actively creating and successfully passing individual learning processes through guidance-on-demand. In the end, the coach (i.e. the expert) offers support in case of difficulties (i.e. scaffolding), provides hints, feedback and recommendations, and eventually takes over certain steps for solving the given problem. However, the coach only appears when explicitly being called by the person to be coached (i.e. like a help system) and the scaffolding is gradually fading as the learning novice proceeds. So, coaching seems to be a very useful concept for sharing and developing simulation knowledge in practice as it aims to develop heuristic strategies through establishing a culture of expertise and with this goes far beyond pure learning as typically provided in workplace learning environments.

5. SUMMARY AND CONCLUSIONS

To the same extent as a new simulation project provides another challenge to model building, experimentation and interpretation of results it rarely can be planned comprehensively and in all details. Therefore, the simulation knowledge stakeholder cannot be fully replaced by algorithms in a simulation project. Instead his/her intuitive power and experience is needed to appropriately and creatively cope with the unexpected. Here, challenges typically consist in enabling or strengthening purposeful interaction between the simulation model and its user, supporting the user in bringing in his/her simulation knowledge, and overcoming barriers hindering in distributing and sharing knowledge and experience for extending the organizational simulation knowledge base and speeding up the learning curve in human resource development.

The paper presents approaches for dealing with those challenges from a knowledge management perspective. Here, the focus is clearly put on the methodological aspect, whereas implementation into simulation tools or supportive systems remains an open task.

Against this background the main message of the paper consists in underlining the key role a human resources play in simulation projects – no matter if we talk about simulation experts, experts from the application area or even novices to those fields. Despite of this, there are many useful methods, concepts and algorithms even coming from other areas that should be applied to simulation-based investigations in order to support the simulation knowledge stakeholder in more efficient and effective problem-solving and sustainable knowledge explication.

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