AssistSim – Towards Automation of Simulation Studies in Logistics

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Abstract Due to the complexity of production and logistics systems, more and more expert know-how is necessary for building adequate simulation models and for designing the right experiments for the requested aims of investigation. To support simulation studies as efficient and high-quality projects, there are different development activities like specialised unit libraries, model generation algorithms, procedure models or decision support systems. Based on the results of the joint research project *AssistSim*, this article presents a new approach of designing and executing experiments as one innovative possibility for support while performing simulations studies.

Introduction

Simulation is a well-established method for analysing and improving processes in manufacturing and logistics systems (e.g. [1] and [2]). Application of simulation methods can support troubleshooting as well as the assessment of planning variants. For example, the automotive industry does not invest in any material flow or manufacturing systems without simulating the systems to justify their decisions. However, the complexity of the systems to be modelled on the one hand, and the degrees of freedom in varying the model parameters to analyse the model and its behaviour on the other hand pose challenges even for simulation experts. In addition reduction of product lifecycles as well as reduced time for modifying production processes necessitate fast simulation results in even shorter time periods.

There are a lot of marketable discrete event simulation software packages with well-defined libraries and features for modelling and simulating manufacturing and logistics processes [3]. The challenges for simulation experts are to prepare valid data, to build valid models, to design dedicated experiments for the given aims of investigation and – all in all – to perform efficient and high-quality simulation studies.

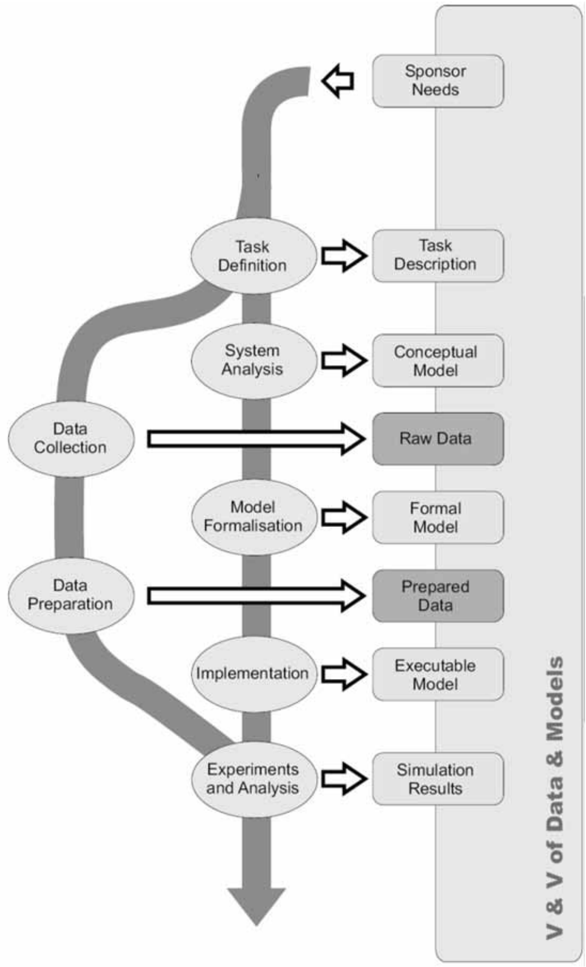

Figure 1. Procedure model for simulation including V&V [4].

One important quality aspect is about the design and the execution of the experiments. *Experiments and Analysis* as one phase of a simulation study (see Figure 1) is based on a valid executable simulation model and the prepared input data for this model.

The experiments depend on the complexity of the system and the aims of investigation, on the model parameters that need to be considered and on the interpretation of the simulation results by the simulation

SNE Simulation Notes Europe – Print ISSN 2305-9974 | Online ISSN 2306-0271
SNE 21(3-4), 2011, 119-128 | doi: 10.11128/sne.21.tn.10077

experts with consequences for the system and the experimental design itself. Incorrect experiments produce unusable results for the given aims of investigation; experimentations with an insufficient number of simulation runs cause statistical inaccuracy or even lack of significance.

Therefore the joint research project ***AssistSim*** (HessenAgentur Project No. 185/09-15) was started in 2009, addressing the experimental design and execution in simulation studies as one of the challenges for simulation experts. The project goal is the development of a decision support software package for a standardised, systematic and semi-automatic design and execution of simulation experiments. The partners of the project consortium managed by SimPlan AG, a German simulation service provider, are the Goethe University Frankfurt, the University of Kassel, INCONTROL Simulation Solutions, Wiesbaden, UST Umweltsensortechnik GmbH, Geschwenda, and representatives of the industry workgroup 'Ablaufsimulation (Process Simulation)' within the VDA (German Association of the Automotive Industry).

In this paper we present the results oft the joint research project. After a short discussion of some related work, the underlying logistics scenario and the defined assistance requirements are pointed out in Section 2. Subsequently the implemented assistance mechanism for simulation experiments divided into the experimental design assistance and the simulation execution assistance are described (Section 3 and 4). *Finally, a discussion of* the results (Section 5) as well as some information about future work (Section 6) *concludes this paper.*

1 Related Work

To enhance the accomplishment of simulation studies for production and logistics and to ensure high-quality simulation results, there are several research efforts which may be classified as follows:

- Procedure Models
- Automatic Model Generation Concepts
- Auxiliary Tools for Statistics, Optimisation or Visualisation
- Decision Support Systems

Procedure models define a systematic procedure for performing simulation studies (for example see Figure 1 or cf. [5] for an extended procedure model), for verifying and validating simulation models, data and results (cf. [4]) or for information acquisition [6] and input data management and validation [7].

Automatic model generation concepts allow an efficient implementation of cost-effective models by utilisation of CAD data and working plan data. Therefore standardised models will be produced. For example, the automotive industry implements different strategies for (semi-)automatic model generation using specialised automotive unit libraries [8], [9], [10].

Auxiliary tools for statistics, optimisation or visualisation are software packages that can be used in addition to the discrete event simulation tools. They include specialised, but standardised functions for optimisation of model parameterisation, automatic execution of series of experiments, or result visualisation. Some tools may be used as an add-on tool only to one simulation package; some tools are implemented as general software for different simulation packages (e.g. [11]).

Decision support systems are computer-based tools which (as discussed in [12], p. 34) are integrated in the day-to-day business operations and are tailored according to the user's tasks, include a dedicated knowledge management, offer alternatives in handling the given tasks and last but not least assist the user to decide efficiently and reliably. Taking the definition above into account there are only very few research projects focused on supporting simulation studies by specialised assistance features. There is, however, one development referring to a tool for scenario definition and navigation for collaborative simulation tasks [13]; another development focuses on the implementation of organisational functions for managing simulation studies [14].

2 Logistics Scenario and Requirement Analysis

In order to derive the assistance requirements during the execution of a simulation study, it turned out to be very helpful to use a specific example. Ideally, this example would not be too complicated and would at the same time illustrate the typical challenges of a real-world production or logistics system. The Institute of Prof. Wenzel at the University of Kassel provides a sample production system (cf. [15]) to the project, which has been developed for their engineering master program. This system, shown in Figure 2, comprises various production resources, conveyors, and an in-process high bay storage.

The set-up of the sample system allows a characteristical analysis such as:

- What is an appropriate configuration for the die casting machines downstream of the bay?
- Is it possible to run the upstream part of the shop in two shifts and the rest of the shop in three shifts?

In order to tackle suchlike rather general questions, they need to be broken down to some objects and object parameters. With regard to the first question one could, e.g., modify the number of die casting machines by adding or removing the fourth machine. Additionally, different dimensions of the storage might impact the utilization of the machines (by better de-coupling breakdowns in upstream areas). And thirdly, the speed of the storage and retrieval machine could improve or worsen the supply of the die casting area.

Today, a simulation analyst most likely would identify the investigation questions of the study, related objects and parameters during system analysis together with planning or application engineers of the real-world system. These questions themselves would be either raised directly by the application engineers, or the simulation analyst would unveil it in interviews bringing in his experiences from earlier simulation projects. Questions, related objects and parameters would be documented in a rather informal way in meeting minutes, presentations or (at best) in a requirements specification typically using the office tools at hand.

After completion of the model building process, the simulation analyst would (usually again together with the application engineer) manually compile a list of parameter variations for the runs of the simulation model. The number of replications per parameter configuration, the run-in period and the test of results on statistical significance would also be done manually and the results would be stored in different ways again (spreadsheets, presentations, sometimes in database tables). The conclusions finally presented by the simulation analyst to the application engineer and his management are again put down in presentations.

This description makes clear that today planning, running and assessing simulation experiments are handcraft with many manual steps (even though an executable simulation model itself is implemented and processed on a computer and even though a couple of auxiliary tools is available; cf. Section 1).

However, an assistance system for experimental design and execution does not only open up room for improving a single simulation study. It might also become a source for knowledge management. If the workflow described previously in this chapter, beginning with the verbalisation of analytic questions down to the assessment of simulation results is supported by a (semi-)automatic software tool, it will be possible to collect information during each step of the simulation project.

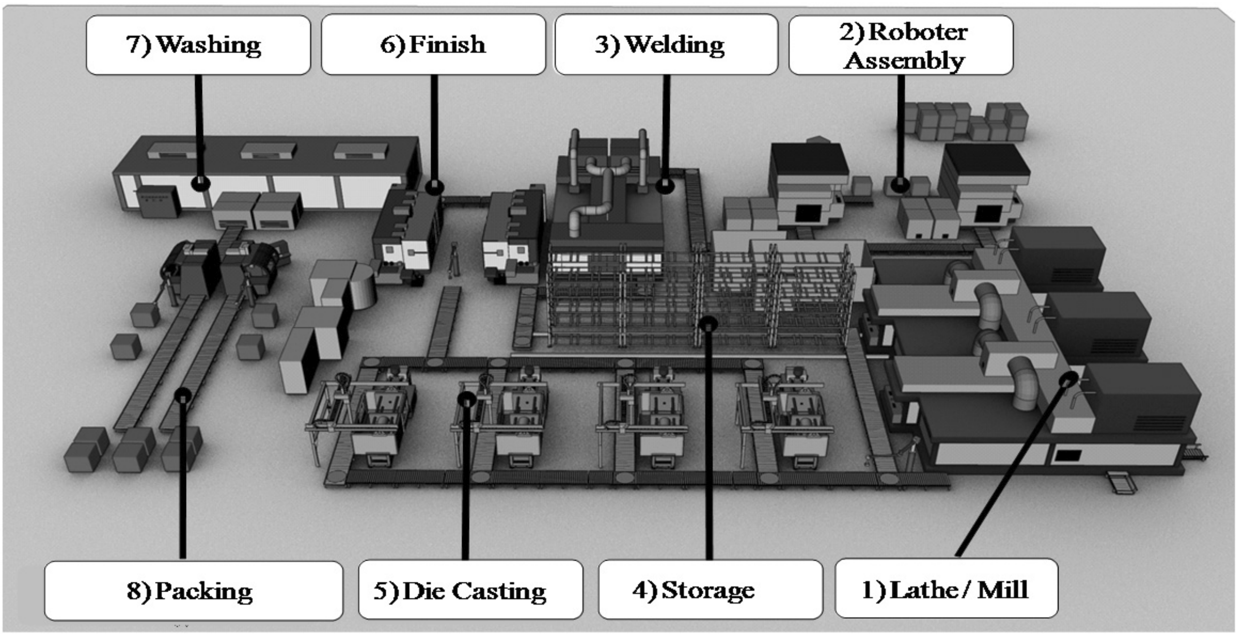

Figure 2. Sample model used for *AssistSim* evaluation (Copyright: University of Kassel, Department of Production Organization and Factory Planning – pfp).

Thus, considering not only one but several simulation studies enables the development and continuous extension of a knowledge base. This knowledge base allows a simulation analyst – whenever a new study is started – to browse questions including associated objects, parameters, run lists and results.

Thereby, the study can be started a lot faster and smoother benefitting from experiences gathered in previous simulation projects. In extension of the current state-of-the-art not only simulation models and model components become re-usable, but (to some degree) project experiences.

The knowledge base, of course, will have to be acquired and maintained by companies and institutions which are using simulation on a regular basis and not only once in a while. But as soon as they are available they might also be proven to be a very valuable assistance for simulation beginners who can improve their learning curve.

As lined out in this section, the features of an assistance system might be arranged following the process steps of a simulation study. This leads to a division in features which support the planning of the study, the formulation of investigation questions etc. and in features which assist preparation, execution and assessment of simulation runs. The latter does have some similarities with experiment managers implemented by some vendors of commercial simulation software packages (cf. Section 1). However, the mechanisms sketched out in Section 4 are not dependent on one specific simulation software. Additionally, some extensive functionality for distributing simulation runs is introduced.

The planning features capturing questions and targets of simulation studies and relating those to objects and data definitely is beyond the scope of existing experiment managers.

3 Experimental Design Assistance for Simulation Studies

The approach of the assistance system for simulation studies is to support and guide the user of a simulation tool throughout the whole simulation study. In detail, this means that the assistance already starts when the user might know nothing more than an initial description of the problems which be solved by using simulation. Here, it does not matter if the user is already a simulation expert or not.

While standard support features of current available simulation tools are limited to the guidance through their own experimental functionalities the aim of ***AssistSim*** is to support the user in setting up the right experiments for his specific problem, and to assist him in performing these experiments correctly.

Hence, the assistance mechanism for simulation experiments has to be divided into two parts:

- Experimental design assistance
- Simulation execution assistance

While the assistance regarding execution and control of simulation experiments is described in the following section 4, the fundamental experimental design assistance concept, so to speak the assistance steps from the idea to the experiment are described in this chapter. The basic structure of the assistance system in both, the experimental design as well as the execution assistance, is shown in Figure 3.

The first step of a simulation study is to define the goals of the study. The goal might be given as an investigation question to be answered, e.g. 'Is the current storage still sufficient in case of a change in volume und content of the orders?' This is a typical verbal formulation of a question which acts as a starting point of a simulation study. Unfortunately, this formulation does not lead to any experiments directly. Thus, the next step has to be the transformation of this informal verbal description of a problem into one or more objectives of investigation which can be analysed by a simulation.

The transformation has normally to be performed by the simulation expert. In case that he is a consultant he has to do this together with the customer. Due to different levels of expertise or experience, this transformation might mislead the whole project. Hence, a support for this basic, but very important step in the experiment preparation is required. The approach of ***AssistSim*** for this step is its integrated reference database in which comparable goals and questions of previous simulation projects are stored. The reference database delivers the concrete objectives of investigation for the given goals based on their integrated checklists (see also [16]).

In case of the example given above, potential objectives delivered by the checklist 'Storage' might be 'Speed of the Automated Storage and Retrieval System', 'Storage Capacity', and 'Storage Policy'.

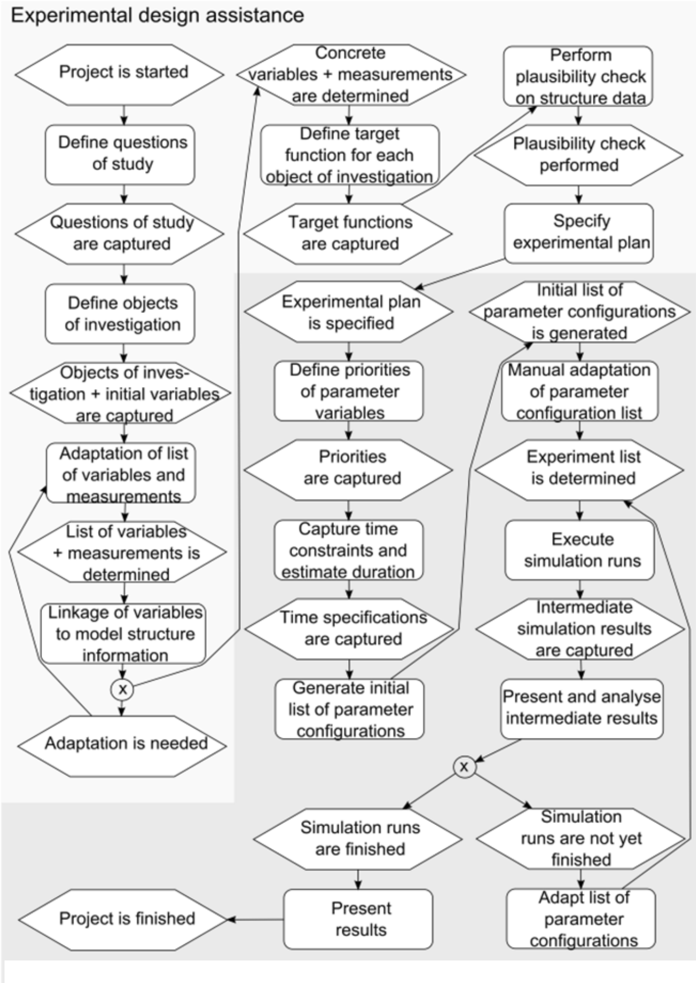

Figure 3. Experimental design assistance and simulation execution assistance

All elements taken from the reference database as well as any inserted or linked data are stored into a project related database by the assistance system. In case that a project goal is not yet available in the reference database the user is able to select a comparable problem. It is also possible to define a new scenario and save it to the reference database later on. By this, the size as well as the expertise of the reference database and therefore its scope of application grows with every new project. According to the objectives, the reference database delivers the corresponding necessary initial variables and measurements. Herewith, the danger of missing an important variable or measurement is reduced. But, if required, the user will be able to enhance or to modify the list of variables and measurements in case that the ones suggested by the reference database do not cover his needs completely, or even if he likes to get insight in additional objectives.

Once the list of variables and measurements is determined, these still model-independent variables need to be linked to the structural information of the underlying simulation model. Basically, this is achieved by setting up references from the tables within ***AssistSim*** to the simulation object specific parameters in the simulation models. These parameters might be collected in tables within the model, or just be given in object specific user interfaces.

During this process it might become obvious that the list of variables and measurements needs further adaption. Thus, the ***AssistSim*** application offers this capability of a manual adaptation as well.

Once the list of linked variables and measurements is finalised, the user is assisted in defining target functions for each selected objects of investigation. In case of the example given above potential target functions could be e. g. 'Maximise the storage capacity', and 'Maximise the throughput of the storage where the minimum throughput is never less than 1.500 entities per day'. When the target functions are captured and stored into the project related database, a plausibility check on the structural information of the current model has to be performed. This test is necessary to ensure that the available information and data can be used in order to achieve the goal of the simulation study. If, for example, the given range of values of a certain parameter indicates that a single component specified in the model will never achieve the performance level which is necessary to fulfil the given restrictions, the dataset, or even the target functions have to be adapted or improved.

Once the plausibility check is successful, the final step of the experimental design assistance, the specification of the experimental plan starts. In this process step the user is assisted in configuring the value ranges of all the parameters defined as variables. These ranges will be used in several simulation runs during the experiment in order to determine the most adequate set of parameters to achieve the requirements formulated in the target functions.

When the value ranges as well as the increments are set for all variables, the experimental plan is captured in the project database, and the design of the experiment is finished.

Afterwards the user can choose whether to start the experiment immediately by selecting the simulation execution assistance, or just to save the preparation of the experiment in the database for use at a later point of time.

The assistance in designing a simulation experiment as described above is not yet known in or for any available, commercial simulation tool. However, most of the possible mistakes are done especially in these early steps of a simulation study, and lead to wrong or at least not usable simulation results. Furthermore, some of the steps from an informal problem description up to an experimental plan are somewhat challenging when a user performs them manually, especially, if the user is less experienced. Knowing this, some people decline to use the method of simulation in order to solve problems.

Hence, the functionalities of the assistance system for designing simulation experiments are quite a big step ahead, and will ease the use of simulation. By this, simulation becomes more attractive to a broader audience. Once the experimental design of a simulation study has been completed, the information needed for the actual execution of the desired simulation runs is provided. The different process steps of the simulation execution assistance are shown in the second part of Figure 3.

4 Simulation Execution Assistance

The specification of the experimental plan can be seen as the interface between experimental design and simulation execution assistance. In the first step of the execution assistance, priorities for the single parameter variables can be defined. The priorities can be used to determine the execution sequence of the simulation runs. Additionally, it will be possible to set time constraints if desired, i.e., to determine how much time is provided for simulation runs, and to estimate the duration for all experiments. With the provided information, it is also possible to compute the expected maximal number of replications of the simulation runs under consideration of the time constraints. The initial list of parameter configurations is generated and can be adapted manually by the user, before the actual execution of the simulation runs is initiated. Intermediate results can be evaluated automatically by the system. Depending on this analysis, the list of parameter configurations as well as the number of replications can be adapted in order to meet pre-specified requirements. After all simulation runs are finished, the process ends.

In the following subsections we describe the key concept of parameter configurations, the execution and control of the simulation runs, as well as the statistical evaluation which is performed during or after the execution of simulation runs.

4.1 Parameter Configurations

For the approach presented here, we assume that an executable simulation model is given, i.e., synthesis or adaptation of a simulation model is excluded. The provided simulation models consist of a set of parameters which can be varied and a set of measurements which are captured during simulation runs. We distinguish between parameter definitions and parameter instances (or shortly, parameters).

The parameter definitions have been defined during the experimental design. Each parameter definition consists of a parameter identifier and a parameter range. Parameter ranges are either interval-based or consist of a finite set of possible values. In the first case a lower and upper bound restricts the possible values of a parameter and a step size is defined in order to determine the level of granularity to investigate such an interval-based parameter.

While the set of parameter definitions and their ranges define the total parameter space to be taken into account, a parameter configuration can be seen as one individual assignment of parameter values to all defined parameter definitions.

Consequently, one parameter configuration can be used to parameterise the simulation model in accordance with the specifications of the experimental design assistance.

4.2 Simulation System Control

The simulation system control has two major tasks: 1) to identify which parameter configurations have to be executed and 2) to actually perform simulation runs in interaction with the simulation system.

In the first case, the strategy of identifying the next parameter configuration depends on the type of simulation study which is currently performed. If it is an optimisation task, an optimisation algorithm will determine the parameter configurations considered in the next step. In the case of an explorative study, a systematic execution of parameter configurations is performed. For such explorative simulation studies three different modes are defined in our approach (illustrated in Figure 4):

1. Replication-based execution
2. Parameter configuration-based execution
3. Automated parameter configuration-based execution

The replication-based execution generates one replication for each parameter configuration before the next replication of a parameter configuration is simulated. This leads to a 'fair' distribution of computation time to all parameter configurations.

The parameter configuration-based execution performs a desired number of replications by iterating through the sorted list of parameter configurations, i.e., all replications are generated for one parameter configuration before the next parameter configuration is taken into account. Using this strategy, the focus lies on performing the simulation runs for those parameter configurations with a higher priority first.

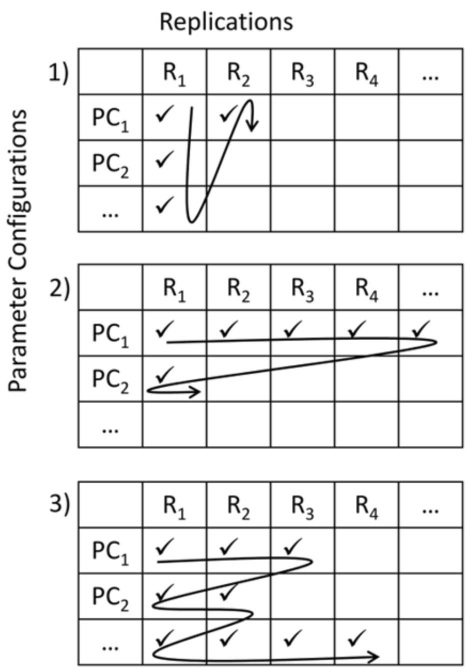

Figure 4. Strategies for performing the simulation runs based on given parameter configurations (PC) and replications (R).

The third strategy is similar to the parameter configuration-based strategy but does not necessarily generate the maximal number of replications for each parameter configuration. Before initiating the next simulation run of the current parameter configuration it is checked if the confidence interval widths of all measurements are small enough in order to provide a (user-specified) sufficiently accurate value by taking into account the replications performed so far. This can lead to different numbers of replications for different parameter configurations.

For the execution of simulation runs, simulation jobs are sent to a simulation server which is able to distribute the jobs (i.e., simulation model, parameters, and seed values for the random number generator) to different simulation nodes.

4.3 Statistical Evaluation

A statistical evaluation can be performed in different contexts. Basic statistics are computed for every simulation measurement (e.g., manufacturing output) taking into account all measurement values of the different replications of a certain parameter configuration. The basic statistics consist of the following values:

- Minimal and maximal value
- Number of replications
- Mean, median
- Standard deviation, variance
- Sum
- 25% and 75% quartile values
- Interquartile range
- Confidence interval width (one-side)
- Skewness of the distribution
- Mode (lower and upper bound)

If a specific level of detail (desired maximal confidence interval width) is specified for a measurement, the automated parameter configuration-based execution (see Section 4.2) will compare the confidence interval width of the replications' results to the desired maximal width in order to decide if more replication runs are to be performed for a parameter configuration.

Additionally to these basic statistics, the statistical evaluation allows for performing statistical significance tests in order to compare the results of different parameter configurations with respect to a particular measurement.

It is possible to specify a set of parameter configurations which should be compared and a pairwise t-Test is then performed and the corresponding probability-values are captured. These results can then be used in order to decide if a parameter configuration can be assumed to be superior to others.

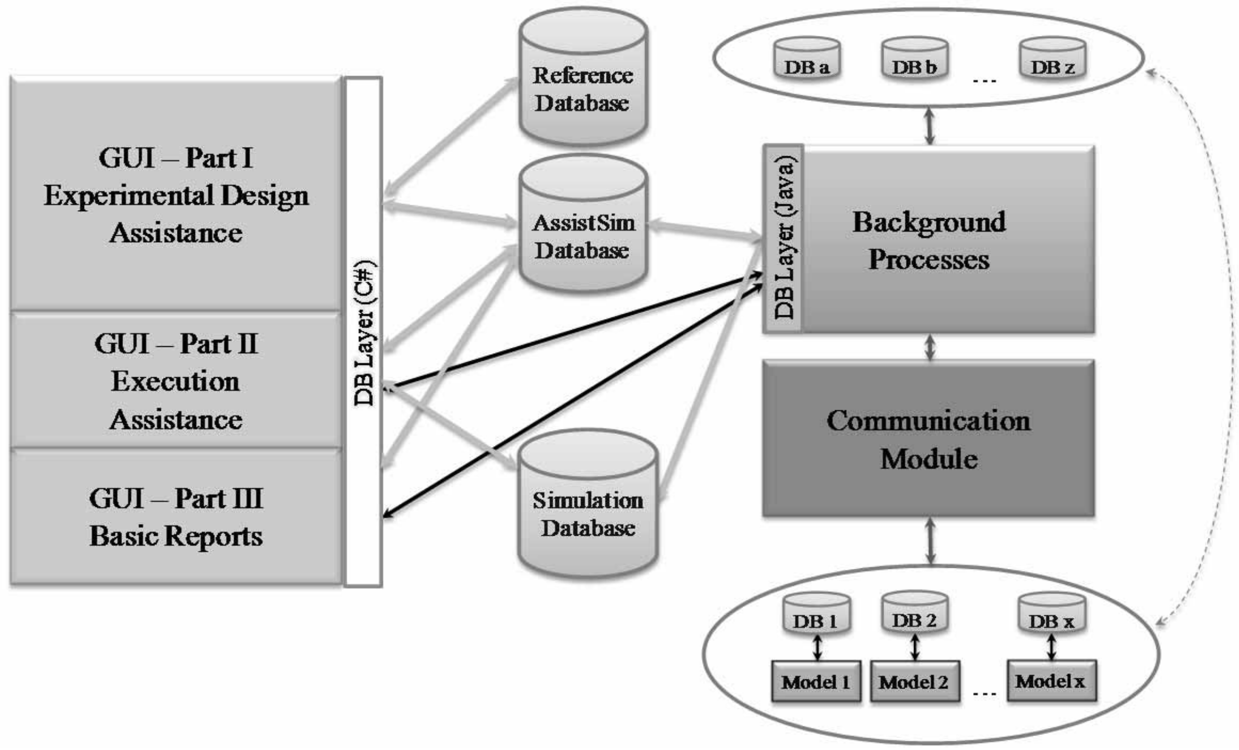

Figure 5. Components of *AssistSim* Software Prototype (DB – Database, GUI – Graphical User Interface).

Additionally to these basic statistics, the statistical evaluation allows for performing statistical significance tests in order to compare the results of different parameter configurations with respect to a particular measurement. It is possible to specify a set of parameter configurations which should be compared and a pairwise t-Test is then performed and the corresponding probability-values are captured. These results can then be used in order to decide if a parameter configuration can be assumed to be superior to others.

If more than two parameter configurations are compared, the thresholds for the significance values will have to be adapted in order to take into account the multiple testing issues and to avoid misleading interpretation of the significance tests' results.

5 Project Results

A large subset of the features described in the two preceding sections has been implemented in a software prototype during the joint research project ***AssistSim***. The software architecture of this prototype does have several components as depicted in Figure 5.

There is a user interface to guide simulation experts through the process of designing experiments and executing simulation runs. Currently, the user interface also offers some basic reporting features (meant to be extended to some sort of reporting assistance). The related data (questions, objects and object parameters, data, parameter configurations, run lists, results etc.) are stored in the ***AssistSim*** database. A reference database serves as the knowledge base and provides information from earlier simulation studies.

Furthermore, there is a module for background processes such as run list generation and prioritisation, statistical evaluation etc. And finally, another component is responsible for the distribution of runs to several client computers in a computer network and for the control of these runs.

Note, that this communication module requires another piece of software to be installed on each client computer. In order for a client computer to be used for simulation runs, it needs (in addition to the communication software) to be equipped with a simulation software license of the respective simulation software package and it needs to have some spare processor capacity.

AssistSim is set up in such a way that it in principle can be connected to any simulation software package using a specific communication interface. This interface has been tested for Siemens PLM simulation tool Plant Simulation and for INCONTROL's simulation tool Enterprise Dynamics [17].

Until now, the ***AssistSim*** software prototype has been tested by some of the German car manufacturers (BMW, Daimler, VW) which are collaborating within the VDA (cf. [18]). Some intensive testing was also done using the sample production system shown in Figure 2.

The test results led to some minor changes and bug-fixing of the software. In general, the results proved the underlying concept of guidance and assistance throughout designing experiments and experimentation to be working goal-oriented and efficiently. Of course, since the software still is a prototype some refinements to the user interface and some other parts of the implementation are required. However, during the next month there are two tracks for improvement and enhancement: firstly, a related research project has been started just recently (cf. Section 6) and secondly and more importantly, the partners feel very confident about the benefit of the assistance functionalities that the development of the system will go on.

6 Conclusion and Future Work

The joint research project ***AssistSim*** has addressed different aspects for assistance while performing simulation studies. The focus of the project was set to two particular tasks of such a simulation study: the experimental design and the simulation execution.

The experimental design is supported by means to capture relevant information about principal questions of the simulation study up to the detailed identification of objects for investigation.

After finishing this task, parameter variables and measurements are identified and linked to the corresponding structure of the simulation model. The execution assistance performs a systematic investigation of the parameter space and initiates simulation runs in interaction with (potentially distributed) simulation systems and stores the corresponding simulation results of specified measurements in the ***AssistSim*** database. These results are then used in order to compute various statistical values and to perform statistical significance tests.

An extensive evaluation of the prototype developed within the project at different project partners from the automotive industry has indicated that the developed assistance functionalities are actually seen to be very helpful for the performance of simulation studies. The simulation expert is assisted in planning simulation studies in a systematic way. Additionally, the automated execution and control of simulation runs is a convenient way to perform many (parallel) simulations for the investigation of certain aspects of the simulated system and to capture results and statistical information about these runs.

The ***AssistSim*** project has mainly addressed the experimental design and simulation execution as tasks within simulation studies. For complex simulation models, an extensive amount of input data to build up the simulation model might be needed. Additionally, complex simulation studies can also lead to large amounts of output data which should be evaluated.

Due to the high relevance of an adequate capturing of input data and the evaluation of the simulation output data, we are investigating potential assistance functionalities for these tasks in the new joint research project EDASim – Development of a Data Assistance for Simulation Studies in Production and Logistics (Hessen Agentur Project No. 260/11-06).

Acknowledgements

The content of this paper is a partial result of the ***AssistSim*** project (HessenAgentur Project No. 185/09-15) which is funded by the European Union (European Regional Development Fund – ERDF) as well as the German State Hessen in context of the *Hessen ModellProjekte*.

We would like to thank all our project collaborators of the ***AssistSim*** development team for their effort in the conceptual design and development of the system, namely Björn Bockel, Tjorben Bogon, Markus Holzner, Ulrich Jessen, Pascal Katzenbach, Alex Müller, Markus Schmitz, René Schumann, and Stephan Stauber. We would also like to express our gratitude to our industry partners – the VDA industry workgroup 'Ablaufsimulation (Process Simulation)', in particular Gottfried Mayer (BMW Group), and UST Umweltsensortechnik GmbH, in particular Christian Loos, – for their valuable contributions in different phases of the project.

References

[1] J. Bayer, T. Collisi, S. Wenzel (Hrsg.). *Simulation in der Automobilproduktion*. Berlin: Springer, 2003.

[2] S. Wenzel, P. Boyaci, U. Jessen. *Simulation in Production and Logistics: Trends, Solutions and Applications.* In W. Dangelmaier, A. Blecken, R. Delius, S. Klöpfer (eds.): Advanced Manufacturing and Sustainable Logistics. Proceedings of the 8th International Heinz Nixdorf Symposium, IHNS 2010, Paderborn, April 2010, S. 73-84.

[3] J.J. Swain. Simulation *Software Survey*. *OR*/MS Today, October 2009, http://www.orms-today.org/orms-10-09/frsurvey.html (online: 25. July 2011).

[4] M. Rabe, S. Spieckermann, S. Wenzel. *Verification and Validation for Simulation in Production and Logistics*. In: SNE Special Issue 2009 'Quality Aspects in Modelling and Simulation', 8/2009, pp. 21-29.

[5] H. Pitsch, O. Rose, S. Wenzel. *Quality Aspects in Simulation Studies for Production and Logistics*. In: SNE Special Issue 'Quality Aspects in Modelling and Simulation', 8/2009, pp. 5-11.

[6] S. Kuhnt, S. Wenzel. *Information Acquisition for Modelling and Simulation of Logistics Networks*. In: Journal of Simulation (2010) 4 - published online 6. November 2009 doi10.1057/jos.2009.9, pp. 109-115.

[7] A. Skoogh, B. Johansson. *A Methodology for input data management in discrete event simulation projects*. In: S. J. Mason; R. Hill; L. Mönch; O. Rose; T. Jefferson; J.W. Fowler (eds.) Proceedings of the 2008 Winter Simulation Conference. pp. 1727-1735. IEEE Omnipress, 2008.

[8] S. Jensen. *Eine Methodik zur teilautomatisierten Generierung von Simulationsmodellen aus Produktionsdatensystemen am Beispiel einer Job Shop Fertigung*. Dissertation, Universität Kassel, 2007.

[9] T. Rooks. *Rechnergestützte Simulationsmodellgenerierung zur dynamischen Absicherung der Montagelogistikplanung bei der Fahrzeugneutypplanung im Rahmen der Digitalen Fabrik*. Dissertation, TU Clausthal-Zellerfeld, 2009.

[10] S. Strassburger, S. Bergmann, H. Müller-Sommer. *Modellgenerierung im Kontext der Digitalen Fabrik - Stand der Technik und Herausforderungen*. In G. Zülch, P. Stock (eds): Integrationsaspekte der Simulation: Technik, Organisation und Personal. Karlsruhe, KIT Scientific Publishing 2010, S. 37-44.

[11] INCONTROL Simulation Software B.V. *Enterprise Dynamics Experimentation User Guide, 2009.*

[12] B. Hellingrath, M. Kloth, M. Kluger, S. Wenzel. *Assistenzsystem unterstützt Planer und Betreiber*. Materialfluss und Logistik, Sonderpublikation, 1996, S. 32-38.

[13] R. Bijlsma, V. De Gast, E. Valentin. *Deploying Decision Support Systems Based on Simulation Models*. In M. Rabe (ed.): Advances in Simulation for Production and Logistics Applications. Stuttgart: Fraunhofer IRB Verlag, 2008, pp. 531-544.

[14] L. März, M. Saler. *Ein Analyse-, Planungs- und Entscheidungsinstrument für Lagerlogistikanwendungen*. In M. Rabe (ed.): Advances in Simulation for Production and Logistics Applications. Stuttgart: Fraunhofer IRB Verlag, 2008, pp. 237-245.

[15] S. Wenzel, B. Bockel. *Ausbildung in der Digitalen Fabrik – Qualifizierung in Produktion und Logistik durch digitale Planungsmethoden*. In M. Schenk (Hrsg.): Virtual Reality und Augmented Reality zum Planen, Testen und Betreiben technischer Systeme. 4. Fachtagung zu Virtual Reality, 27.-28. Juni 2007, Magdeburg, S. 219-224 (CD-ROM).

[16] B. Bockel, M. Schmitz, S. Wenzel. *Entwicklung von Methodiken zur systematischen Planung von Experimenten in Simulationsstudien.* In G. Zülch; P. Stock (Eds.): Integrationsaspekte der Simulation: Technik, Organisation und Personal. Karlsruhe, KIT Scientific Publishing 2010, S. 363-370.

[17] INCONTROL Simulation Software B. V. *Enterprise Dynamics 8.2.* 2011.

[18] G. Mayer, C. Pöge. *Auf dem Weg zum Standard – Von der Idee zur Umsetzung des VDA Automotive Bausteinkastens.* In G. Zülch, P. Stock (Eds.): Integrationsaspekte der Simulation: Technik, Organisation und Personal. Karlsruhe, KIT Scientific Publishing 2010, S. 29-36.

Submitted: September, 2011
Accepted: November 30, 2011