AUTOMATED EXCHANGE SYSTEM BETWEEN SIMULATION, VISUALIZATION AND CONSTRUCTION TOOLS

David Weigert[(a)]

[(a)] Otto-von-Guericke-Universität Magdeburg, Magdeburg (Germany)

[(a)]david.weigert@ovgu.de

ABSTRACT

In today's planning processes, it is necessary that assembly processes, component transport to the production facility and the use of components are optimally matched. To realize this matching, these processes must be carried out as detailed as possible. This is where the conflict between the least possible effort in the bidding phase, in which the focus is on the fast creation of a basic factory layout and an appealing communication of the planned system.

By increasing costs, lack of time and cost-intensive physical hardware devices production industry respond to these increasingly with digital planning tools in product development. Through the development of an automatic exchange system between simulation, visualization and construction tools a possibility should be developed to combine intralogistics systems from any planning tools of the digital factory. The use of open source standard AutomationML forms the basis of the automatic exchange system.

Keywords: modern automation system, system planning, AutomationML, automatic model creation

1. INTRODUCTION

Due to ever shorter product life cycles, the versatility, speed and flexibility of origination, production and logistics processes becomes a stronger focus (Schenk 2014). The use of digital tools of simulation, visualization and design increases the quality of planning, increases the efficiency and shortens the product development and launch (Schenk 2014; Daft 2016; Klepper 1996; Lüder and Schmidt 2015). All these benefits can only be fully exploited if it is possible to combine all relevant and previously isolated digital methods, tools and models into an integrated planning system (Faltinski 2011; Schreiber and Zimmermann 2011). The used digital tools in the areas of simulation, visualization and construction provide a comprehensive range of solutions to various problems. The long-term use of simulation, visualization and construction tools in the planning of intralogistics material flow systems clearly shows that over time individual and specialized tools were developed. They have only limited possibilities to offer and share planning data in a heterogeneous system landscape (Faltinski et al. 2012; Rawolle et al. 2002).

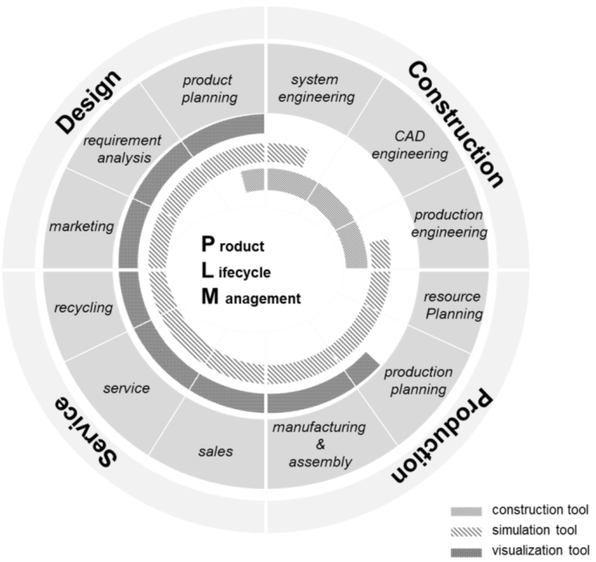

Figure 1 Application of simulation, visualization and construction tools in the PLM cycle

The existing digital tools are partially only for certain functional areas of PLM-cycle as shown in Figure 1. In practice, therefore is no comprehensive, computer-assisted planning of intralogistics systems and production areas. It lacks a neutral exchange format for the mapping of simulation data, geometric construction drawings and visualization of current detailed production and logistics processes. A tool which relates the three most important tools of the digital factory represents the automatic exchange format, which will be explained in detail in the following sections.

2. LITERATURE REVIEW

The complexity and the cost pressure in the PLM are constantly increasing (Eigner and Stelzer 2009). The standardisation of systems, processes, and components is an important means to cope with the future challenges (Drath 2008). The PLM is defined by the overall process of product development with its various steps. A target State of the process, as well as the control of all necessary steps to set and planned (Sendler 2009). The previous focus was the combined planning phases to shorten the time-to-market of products through the integration of product, process and production system planning, the present claim is consists of early reliable data product development for the integrated production, to use factory system development and design (Schenk 2014; Schenk and Schumann 2008). The idea of combined planning phases is described for years by modern and powerful tools (Dangelmaier 2013). There is here a number of special cases. These include individually prepared solutions and are sufficient for concrete problems. However, the lacks comprehensive planning approach to take part in processes to promote an integration of all. A first approach was developed for continuous digital planning and controlling with the enterprise application integration (EAI) and the service-oriented architectures (SOA).

The EAI represents integrated business processing along value chains. Corporate applications of different generations and architectures can interact through a common network (Aier 2004, 2006; Kaib 2004). The SOA describes a method encapsulates the existing computerized components such as databases, servers, and sites in services and coordinate so that their services can be grouped together to higher services and made available to other departments of the Organization (Bieberstein 2008; Liebhart 2007). Goals are the long term reduction of costs in the development of production plans and a greater flexibility of business processes by reusing existing services. The costs of future developments are reduced, because all necessary services are already available and these must only be set should be. Reason for the sluggish development is due to the high requirements for data security, continuity of the tool development and uncertain systems and product development (Fay 2006; Drath 2008; Raupricht et al. 2002).

The combined, continuous flow of information between the used tools has emerged in view of increasing shortening and linking the phases as valuable. Therefore, a comprehensive planning tool in the areas of planning, implementation and realisation is gaining in importance. The interplay of different digital planning tools within the product life cycle is summarized often under the term "Digital Factory". Here, the term describes a comprehensive network of digital models and methods of including the simulation and 3D visualization. Its purpose is the holistic planning, implementation, control and continuous improvement of all major factory processes and resources in conjunction with the product (VDI 2008; Wenzel et al. 2003).

A combination of different planning tools is also known. According to the current state of science no consistent and open source system exists to exchange data between the tools properly, efficiently and effectively. The use of continuous planning tools lacks. The motivation for the use of a common tool can be the reduction of costs for the planning, control, and operation and maintenance of equipment.

3. REQUIREMENTS AND IMPLEMENTATION

Three individual tools are linked by an automatic exchange system. Figure 2 shows the cross-section functions of the individual tools.

Tool for: / ability to:	simulation	visualization	construction
simulate		◐	○
visualize	○		◐
construct	○	○	

○ low ◐ medium ● high

Figure 2 Overview of the tools and their abilities

The expert knowledge and the complexity of each tool are very high. By separate cross functions of the individual tools, it is difficult to find a common level. The presented development is an application-oriented middleware and thus represents no additional tools. While the visualization tool offers the possibility of simple stochastic influences but cannot depict a classical discrete event material flow simulation. Another example is the construction tool. The construction tool cannot represent a material flow simulation, but constructed models can be shown in three-dimensional view, that can be interpreted as a simple visualization. The following are the benefits of the automatic exchange system:

- **Lossless and accelerated modeling and conversion:** within the three different tools
- **Avoid new investments:** used simulation, visualization, and construction tools in the company will remain
- **Neutral Exchange format:** leads to any figure of the models and access to different tools

With the simulation tool, software solutions are referred to the discrete event, continuous or discrete-rate modeling and simulation of material (Reggelin 2011). A 3D visualization and animation to the validation refers to the visualization of design planning, interdisciplinary communication and sales presentations of production and logistics systems. The construction tool describes a software solution for the computer-aided technical drawing to create virtual models of three-dimensional objects.

3.1. Exchange format AutomationML (AML)

To enabling the exchange of information between the tools, it is necessary to use an open, non-proprietary and standardized language. By Format AutomationML (AML) (Automation Markup Language) is the internationally standardized in the IEC62424 data format CAEX (Computer Aided Engineering Exchange) as well as the implementation platform and independent Data exchange format XML (Extensible Markup Language) used (Figure 3).

The standard AML supports the definition of semantic roles and classes. Since AML indeed possesses the technical requirements for the modeling of production, intralogistics and material handling systems, however so far mainly in the field of virtual commissioning, robot systems and the general geometry of exchange used to exist only few and rudimentary provided with properties AML descriptions Material flow and logistics systems (Hoernicke et al. 2016; Hundt et al. 2009; Lüder and Schmidt 2015). Existing intralogistics material flow systems as CAD drawing can thus be passed into the visualization tool without create additional elements. This is done by linking role profiles. In addition to the geometry of an element the thereon objects, technical parameters and environment variables are passed. Here the developed standardization serves to link the properties of an element, object or the parameters within a tool with the AutomationML environment.

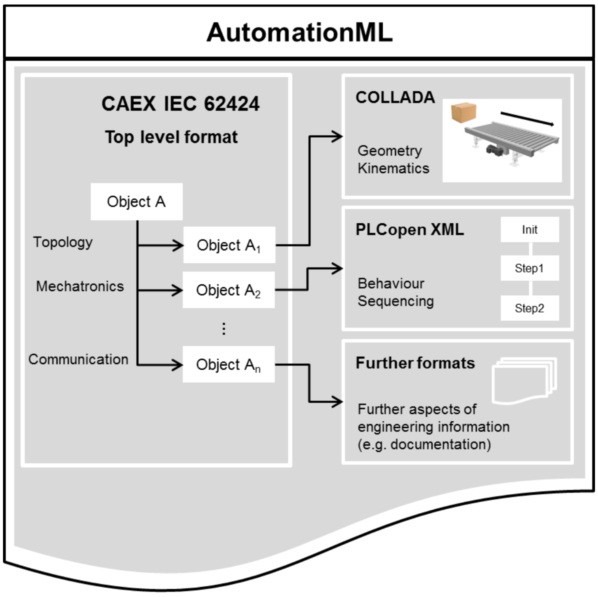

Figure 3 Content and function of AutomationML

4. AUTOMATIC EXCHANGE SYSTEM

Linking the tools in the automatic exchange system allows visualization models in simulation models to convert. A comprehensive up to date step, since the discrete event simulation allows a very detailed and custom modeling. The discrepancy between the implementation of visualized simulation-based models will be reduced by the development. The figure shows the interaction of the participating tools with automatic exchange system. The objective is to provide this omnidirectional appearance and parameters for different tools. A time-consuming and multiple modeling and setting should be avoided. The core functions of the automatic exchange system describing the export of data from the tool in the automatic exchange system, the processing of data in the AutomationML format and import into the target tool. This all takes place automatically and is supported in conflicts through a guided conflict resolution. The specificity of development is this ability formats in the AutomationML format to convert to transfer existing data from the tools and to guide the user through the import and export. By working completely different software environments can be passed this false or nonexistent model elements and other parameters or missing. The user can complete missing content in addition. This function is used particularly in the exchange between simulation and visualization. Due to the different levels of detail and parameter in these two tools here is increased potential for conflict in the Exchange of models and parameters (Figure 4).

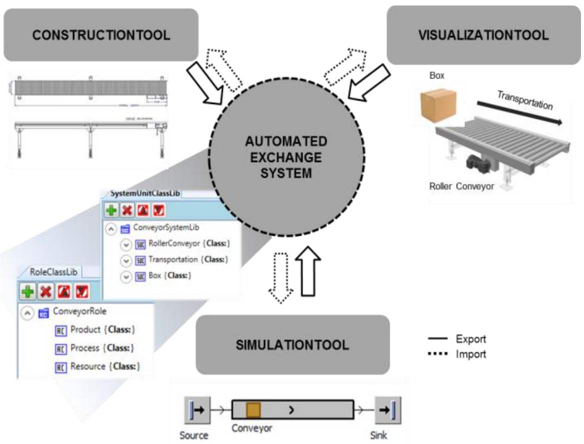

Figure 4 Overview of the integration of the automatic exchange system

To obtain the high degree of customization of simulation and design tools, rules are initialized around objects, parameters and descriptions without error to transfer. Since it is not possible to see all user-specifiable elements before and after an image in the AML Exporter, and from AML in the importer predefine, a tool was developed, with which he can provide the necessary information for a picture itself. The basis for the picture one created by the user rules for mapping between objects or object hierarchies and their attributes. In preparing this set of rules, the user is supported and guided by the developed software. The Figure 5 shows the conceptual approach to the data transfer of the three tools on AML.

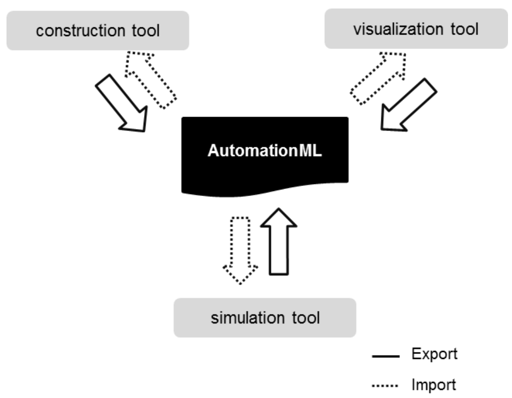

Figure 5 Transfer of data from the tools in AutomationML

The data transfer process essentially consists of two steps, the export in the AML environment and importing into the target tool.

4.1. Import function

The Import describes the transmission from the AutomationML file into the target tool (s. Figure 6). In the simplest case, the data from a source tool that already used for producing the data set a block catalog with an existing set of rules derived. This rule set may have been either created by the user himself at an earlier time, or by a third party as part of a service.

In this simple case, the user selects in an import dialog from the one to use ruleset and then start the import process, which is then completed according to the defined rules. If the imported data does not contain all the information necessary for a complete and unambiguous generation of the target record from the perspective of import target tools, so be where possible defaults assumed and the user then referred to this in order to facilitate a manual review. If no block of mapping rules consists for the data to be imported, the user is given the possibility to create this itself. The functions of the importer in detail:

1. **SourceDataReader:** Captures the attributes of the trainees from object from AML-file
2. **Rule-Interpreter:** uses object attributes to the illustration in the target system
    - matching library item
    - matching Parameters of the object (speed, length, etc.)
3. **TargetDataWriter:** After successfully mapping of the Rule-interpreter, he creates an instance of the appropriate library element or group of elements in the target system

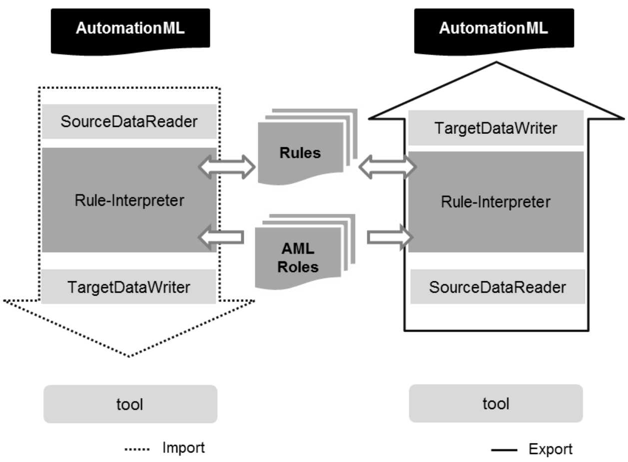

Figure 6 Functioning and structure of the Importer and Exporter

4.2. Export function

The export function is used to exchange data from the source tool in a AutomationML file. The Exporter is designed similarly to the Importer (s. Figure 6). Here, however, the implementation is less complex because the Exporter cannot make assumptions about the target system and thus largely the tool-internal data format can be used as basis for the exported AML structure. The only adjustment is the unique creation of mapping rules of the internal objects on elements of the AML standards, namely the allocation of system Unit Classes, Role Classes and Interface Classes from the standard libraries previously defined, where possible. This is especially the transfer of semantic information between tools and thus greatly increases the quality of data exchange and to simplify the mapping rules on the import side of the data exchange. The functions of the Exporters in detail:

1. **SourceDataReader:** recorded attributes of the object from the source system
2. **Rule-Interpreter:** searches based on object attributes to the figure in AML
    - Matching system-unit-class (SUC) (E.g. rotary table)
    - Matching AML role definition (E.g. conveyor, Rotary element...)
    - Matching Parameters
3. **TargetDataWriter:** by the Rule-interpreter, a corresponding AML-file is written after successfully matching

5. USE IN MATERIAL FLOW SIMULATION

In addition to exchanging the system description and structure, it happens during the design phase of a plant as well as later adaptations that a virtual system image with data from real or simulated production processes to be linked. Applications include for example:

- Visualizing a simulated production layer for communication bottlenecks and opportunities for improvement
- The reproduction of recorded live production data for problem analysis
- The visualization of the modified plant behavior in adjustments in intralogistics

In the above cases, in turn, a data exchange of simulation or production monitoring systems to planning and visualization systems is necessary, but not the investment structure has to be communicated, but the temporal change of the material flow. It was joined by the previously known tools as well as the proposed AutomationML formats to its limits, because it was designed for the description of the plant structure. For this reason, a new data format and transmission method for communication of runtime data of a system must be developed (Figure 7).

The following transfers are to be made possible:

- Date and type of goods recorded in the system
- Time at which a good leaves the considered system
- Changes of the product position over time
- Changes the position of mobile Anagenkomponenten over time (operator, fork-lift trucks, etc.)
- Dates of transfers of goods from one system component to the next station
- Changes to the product (Assembly, damage, packaging, etc.)
- Data editing processes such as Start- and end times and duration of the process
- In General, concrete values are needed for the modeled sizes for everyone in the plant model with distributions or random numbers

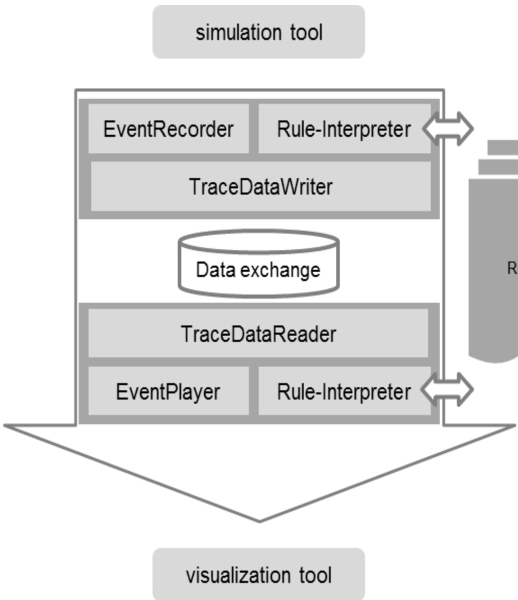

Figure 7 Detailed description of the function in the exchange / feedback between visualization and simulation.

6. THE AUTOMATIC EXCHANGE SYSTEM ON APPLICATION EXAMPLE

To test the development of an automatic exchange system, different examples were developed. Here, the first attempts at exchange of visualization tools were made for simulation tool. The exchange between visualization and simulation is one of the most difficult tasks in the exchange system. This is due to the different levels of detail and different parameterizations within the tools. Where visualizing a detailed reproduction of features, the simulation tool requires a detailed parameterization of the system states.

First, a conceptual model to be visualized the, modeled and simulated system was created. The concept model is the basis for the visualization and simulation. This ensures that both visualization and simulation represent identical models. This facilitates the verification and validation of the models created in the course.

The next step is conceptualized model is transferred to the visualization tool.

The visualization allows a first virtual evaluation of the model. In visualization tool, the system can be shown extensively, but only simple calculations and statements about the system status over time are possible. In order to remedy these drawbacks of the visualization tool, in the next step, a simulation model is created. As a remodeling in the simulation tool is time consuming and a new modeling effort would arise, should be done through the automatic exchange system of this step.

Here, the content is exported from the visualization tool and transmitted in compliance with roles and classes, geometry and kinematics of the elements and objects used in the simulation tool. The transfer of the content was carried out via the interface AutomationML and additional adjustments to the automatic exchange system. The simulation tool the program Tecnomatix Plant Simulation was used. This software for discrete event simulation, analysis and optimization of production processes, material flow and logistics processes is part of Siemens Product Lifecycle Management Software.

6.1. Conceptual model

The basis for the application example is an intralogistics system. The example is based on an existing material flow system and thus describes the common elements of intralogistics. The concept model of the plant is used as a basis for further steps. The logistical objects are transported on conveyor lines (CO) and turntables (RT) to the following stations:

- Processing station (PS) 1,2,3 (Manual picking station)Processing station (PS) 6 (post processing)
- Processing station (PS) 4,5 (Storage in the high-bay warehouse)
- High rack (HR) (Storage of objects)

In addition, read the objects and their properties stored using radio frequency identification (RFID). The figure shows the conceptual model of the system and thus describes the basic function and the relationships of the elements to each other (Figure 8.).

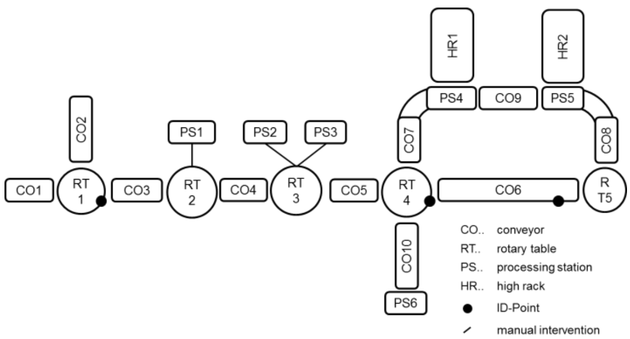

Figure 8 Conceptual model of intralogistical system

6.2. Model in the visualization tool

According to the conceptual model, the intralogistics system was created in the visualization tool. The illustration shows in Figure 9 reaction exemplified in the visualization tool taraVR. The visualization allows a first virtual design of the system and controls with simple priority rules the material flow. Due to the high level of detail, the system can be modeled with a few steps and understandable.

However, there is the possibility of repeated simulation experiments to perform other statements about being able to enter the system.

Table 1 Considered logistical objects in the system

Visualization	Simulation	Sim-Type
ContainerRed	BoxRedFull	Entity
Euro pallet w. raw material	EurPalettFull	Container
Euro pallet w/o. material	EurPalett0	Container
Euro pallet w. material	EurPalett1	Container

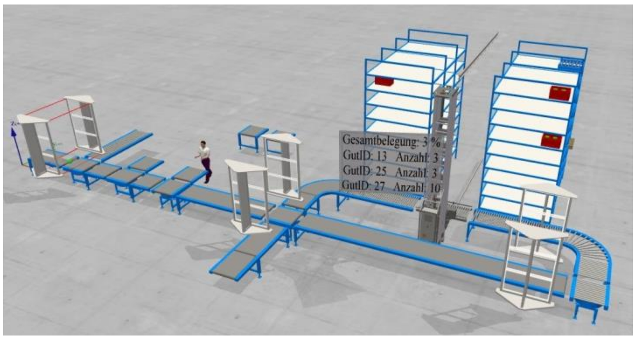

Figure 9 VR of intralogistics system in visualization tool (1)

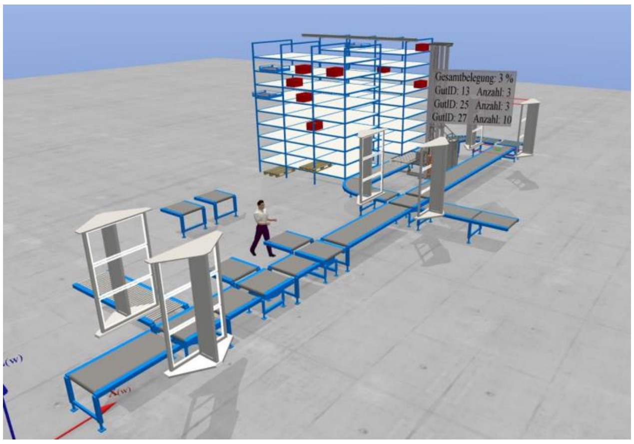

Figure 10 VR of intralogistics system in visualization tool (2)

6.3. Model Description in the automatic exchange system

If a transfer from the visualization in the simulation tool made without the automatic exchange system, a repeated modeling would be necessary. The automatic exchanging system allows a workload by repeated modeling to avoid as a simulation model. The Exports from the visualization create a hierarchy in AutomationML. This hierarchy includes another description of the components, processes and products from the visualization and geometric and kinematic relationships of the content (Figure 9 and Figure 10).

The items from the visualization tool are exported via the developed AML interface in the automatic Exchange System. In the Exchange system, the classes and roles of the objects are created, modified or retained. In this example were created for the project "Blocks", "Processes" and "Products". Then edited and formatted the system the data as described in the chapter 4. Here, all other properties of the objects are applied (location, speed, color, etc.).

After this step, the prepared data on import into the simulation model are passed. Thanks to a programmed surface is enables the user of the modeling process to understand. Furthermore, it is possible when you enter to support. The system can provide work to the user in fact that difficult situations in the creation and parameterization can be solving itself. It comes to a conflict, for example, when creating a new model where is not known whether the problem on conveyor lines or blocks can be depicted, the user support in the selection. He knows how he makes the parametrization of the virtual system. The methods in the simulation tools, networks, and devices create the corresponding model during initialization of the program. This means that subsequent modelling will be as slow as possible.

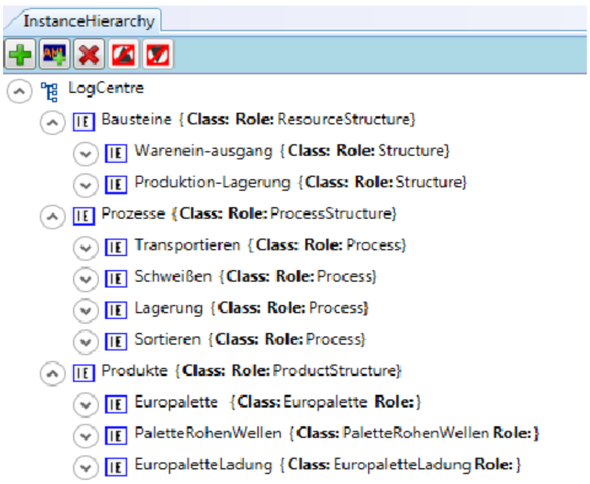

Figure 11 Hierarchies in AutomationML

6.4. Model in the simulation tool

The next step is to convert the model from the visualization tool in the simulation tool. The automatic exchange system helps here in faster modeling. Figure 12 shows the fully converted model from the visualization.

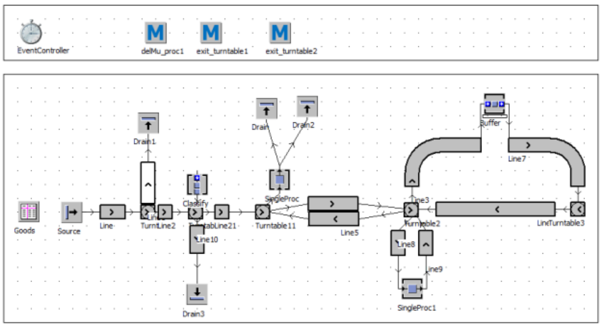

Figure 12 Simulation Model of the intralogistics system after the transfer

The existing settings will provide an initial quantitative images of the model in the simulation tool. Many parameters could be transmitted via the automatic exchange system. It is obvious that a 1: 1 relationship at the moment can never be fully achieved. For this purpose, individual parameterization of the models are too many available. The necessary changes have been covered by the rule interpreter, as well as the user interface.

For the implementation of the model in the simulation tool, the following problems were identified in the prototypical implementation:

- Settings of the transport systems in the simulation tool much more extensively to parameterize as in the visualization tool
- Generating multiple, complex goods from the source must be mapped on a table. A 1:1 relationship of the sources thus not possible
- Parameterization of the employees much more extensively in the simulation tool. Flexibility of staff was carried out via additional method control

The problems could be solved through further parameterization of the respective modules.

Table 2 shows an excerpt from the representation of the different objects of visualization and simulation. Some objects could be easily applied as a component; other objects had to be described by module and method. It is clear that with the high degree of individualization of visualization and simulation model different ways exist to transfer a model from one tool to the next tool. The following table shows extracts the possible combinations for the established example.

Table 2 Excerpt about possible illustrations, and combinations of blocks

Visualization	Simulation	Sim-Library
RT 01	Rotary Table	Materialflow
CO 01	Line	Materialflow
RT 02	Rotary Table + Method	Materialflow + Informationflow
PS 01	PlaceBuffer + Method	Materialflow + Informationflow
HR 01 / 02	PlaceBuffer + Method	Materialflow + Informationflow

7. CONCLUSION

The prototypical example of a first potential and limitations of development outlined. The use of AutomationML enables open source exchange of different tools. In conjunction with an intelligent system for importing and exporting new type of mutual model building can be made possible. The following advantages can be combined with the use of an automatic exchange system.

- Used visualization, design and simulation tools in the company will remain, this avoids heavy new investment
- Synergy effects can be achieved through the use of an Exchange system that combines the individual benefits of the tools
- Visualization, modeling, and simulation of real-world intralogistics systems can be accelerated because of the mostly manual and expensive modeling effort will be reduced
- Multiple implementations of a problem in various tools reduced which results in shorter processing times and increased productivity

The example makes clear how extensive the import and export function must be programmed. In addition, the reference model cannot show all possible errors in the implementation of visualization of the simulation. The overall results of the first phase of development suggest however major advantages. There exists a time advantage over the comparatively new modeling in the automatic conversion. The overall results of the first phase of development suggest however major advantages. There exists a time advantage over the comparatively new modeling in the automatic conversion. Through the implementation of the model from a single source, incorrect or faulty disclosure avoids planning error descriptions and parameterizations. The developed reference models are available following the development for the repeated use of the available. The user interface is developed steadily through constant feedback in the development processes.

8. OUTLOOK

The development of the automatic exchange of information is to facilitate a high potential model building in different tools. The sample results show that the implementation is successful possible. A first approach to the automated model building is managed by automatic Exchange System. Here, no proprietary software solutions were used.

The use and adaptation of open source tool AutomationML is used as a neutral interface between simulation, visualization and construction. With the creation of any model in one of the three tools in the future, it will be possible to produce accurate and rapid models from a single source. This eliminates the costly, error-prone and time-consuming multiple creation of models. The special feature of the coupling with the simulation tool shows that it is possible also in plant simulation is to be able to create an automatic model creation with existing elements.

The example in the implementation of visualization and simulation is one of the most difficult work packages. The used elements are mostly known in the construction. Thus, a simple parameterization and transfer into the automatic exchange system is possible. The construction of intralogistic equipment or the construction of a new element represent only marginal problems of import and export for the system. However, the simulation tool stands for high customization. The Modeler has the choice between different components, networks and methods. A real-world situation can be modeled in the simulation tool on many different levels and adapted. Depending on the goal of the simulation are some items of greater importance and must be modeled more detail than others.

Here, the automatic exchange system offers the possibility of creating a guided model. Conflicts are detected and can be changed by the user. The stronger the user the system interacts with, the more accurate the way of working in the reference libraries of AML is filed. However, for the simulation tool the future issues that should be examined further in the course of the work. Among other things how the illustration can be summarized better standardized elements, how the computing time and computational load may be reduced for larger models, how reference libraries can better portray the intralogistical questions and to what extent in addition to discrete event simulation tools other simulation paradigms and their tools can use for import and export the developed functions.

The described development is a first step for the automatic model creation. This meets the requirements for an integrated planning tool. It is now possible to create joint AML libraries for simulation, visualization and construction, to share and to individualize a repeated use. Future steps are the more detailing and standardization of automated Exchange System.

REFERENCES

Aier S (2004) Enterprise application integration: Flexibilisierung komplexer Unternehmensarchitekturen. Enterprise architecture, vol 1. GITO-Verl., Berlin

Aier S (ed) (2006) Enterprise application integration: Serviceorientierung und nachhaltige Architekturen, 2. Aufl. Reihe: enterprise architecture, Bd. 2. GITO-Verl., Berlin

Bieberstein N (2008) Executing SOA: A practical guide for the service-oriented architect. The developerWorks series. IBM Press/Pearson plc, Upper Saddle River, NJ

Daft RL (2016) Organization theory & design, 12e. Cengage Learning, Boston, MA

Dangelmaier W (2013) Fertigungsplanung: Planung von Aufbau und Ablauf der Fertigung ; Grundlagen, Algorithmen und Beispiele, [Reprint der] 2. Aufl., 2001. Springer, Berlin [u.a.]

Drath R (2008) Die Zukunft des Engineering. Herausforderungen an das Engineering von fertigungs-und verfahrenstechnischen Anlagen. In: Sauer O, Sutschet G (eds) Karlsruher Leittechnisches Kolloquium 2008: [28.-29. Mai 2008 ; Tagungsband]. Fraunhofer-IRB-Verlag, Stuttgart, pp 33–40

Eigner M, Stelzer R (2009) Product Lifecycle Management: Ein Leitfaden für Product Development und Life Cycle Management. Springer-Verlag Berlin Heidelberg, Berlin, Heidelberg

Faltinski S (2011) A dynamic middleware for real-time automation systems. Lemgoer Schriftenreihe zur industriellen Informationstechnik, vol 7. InIT; Technische Informationsbibliothek u. Universitätsbibliothek, Lemgo, Hannover

Faltinski S, Niggemann O, Moriz N, Mankowski A (2012) AutomationML: From data exchange to system planning and simulation. In: Industrial Technology (ICIT), pp 378–383

Fay A (2006) Reduzierung der Engineering-Kosten für Automatisierungssysteme. Industrie Management(22):29–32

Hoernicke M, Messinger C, Arroyo E, Fay A (2016) Topologiemodelle in AutomationML: Grundlage für die Automatisierung der Automatisierung. Atp-Edition : automatisierungstechnische Praxis ; Organ der GMA (VDI-VDE-Gesellschaft Meß- und Automatisierungstechnik) und der NAMUR (Interessengemeinschaft Automatisierungstechnik der Prozessindustrie) 58(5/2):28–41

Hundt L, Lüder A, Barth H (2009) Anforderungen an das Engineering durch die Verwendung von mechatronischen Einheiten und AutomationML. SPS/IPC/DRIVES 2009:341–349

Kaib M (2004) Enterprise Application Integration: Grundlagen, Integrationsprodukte, Anwendungsbeispiele, 1. Aufl., Nachdruck. Wirtschaftsinformatik. Dt. Univ.-Verl., Wiesbaden

Klepper S (1996) Entry, exit, growth and innovation over the product life cycle. American Economic Review, Estados Unidos
Liebhart D (2007) SOA goes real: Service-orientierte Architekturen erfolgreich planen und einführen, 1. Aufl. Hanser, München [u.a.]
Lüder A, Schmidt N (2015) AutomationML in a Nutshell. In: Handbuch Industrie 4.0 : Produktion, Automatisierung und Logistik. Springer Fachmedien Wiesbaden, Wiesbaden, pp 1–46
Raupricht G, Haus C, Ahrens W (2002) PLT-CAE-Integration in gewerkeübergreifendes Engineering und PlantMaintenance. atp – Automatisierungstechnische Praxis(44 (2)):50–62
Rawolle J, Ade J, Schumann M (2002) XML als Integrationstechnologie bei Informationsanbietern im Internet. Wirtschaftsinf 44(1):19–28. doi: 10.1007/BF03251462
Reggelin T (2011) Mesoskopische Modellierung und Simulation logistischer Flusssysteme, [Online-Ausg.]. Universitätsbibl, Magdeburg
Schenk M (2014) Fabrikplanung und Fabrikbetrieb: Methoden für die wandlungsfähige. Springer Berlin Heidelberg
Schenk M, Schumann M (2008) Interoperable Testumgebung für verteilte domänenübergreifende Anwendungen. In: Scholz-Reiter B (ed) Technologiegetriebene Veränderungen der Arbeitswelt. GITO-Verl., Berlin, pp 155–169
Schreiber W, Zimmermann P (2011) Virtuelle Techniken im industriellen Umfeld: Das AVILUS-Projekt - Technologien und Anwendungen. Springer Berlin Heidelberg
Sendler U (2009) Das PLM-Kompendium: Referenzbuch Des Produkt-Lebenszyklus-Managements. Xpert.press. Springer, Dordrecht
VDI (2008) Digitale Fabrik: Grundlagen ; VDI-Richtlinien ; VDI 4499, Blatt 1. Beuth, Berlin
Wenzel S, Hellmann A, Jessen U (2003) e-Services - a part of the "Digital Factory". In: Bley H (ed) Proceedings / 36th CIRP International Seminar on Manufacturing Systems: Progress in virtual manufacturing systems : June 03 - 05, 2003, Saarland University, Saarbrücken, Germany. Univ. des Saarlandes, Lehrst. für Fertigungstechnik, Saarbrücken, pp 199–203

AUTHORS BIOGRAPHY

David Weigert studied Industrial Engineering with specialization in Logistics at the Otto-von-Guericke-University Magdeburg. In several industrial projects he worked on logistical problems on the topics of material flow simulation, requirements planning and factory planning. He became a research associate at the Chair Logistical Systems at the Otto-von-Guericke-University Magdeburg and scientific project assistant at the Fraunhofer Institut for Factory Operation and Automation IFF Magdeburg. His areas of competence are the analysis and optimization of logistics processes, as well as modelling, simulation and optimization of logistics systems. Currently David Weigert is working on his doctoral thesis on the mesoscopic real-time simulation of logistic systems.