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ENTERPRISE APPLICATION INTEGRATION FOR VIRTUAL PRODUCTION

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ABSTRACT

The focus of this work is to promote the adoption of Enterprise Application Integration (EAI) as a framework for virtual production. The product planning phase in real and virtual production usually requires a huge range of various applications that are used by different departments of a company. To increase productivity on the one hand and reduce complexity of application integration on the other hand, it is essential to be able to interconnect the differing syntax, structure and semantics of the distributed applications. The presented EAI framework will be used in the production planning process of a Line-Pipe as a use case. The successful application interconnection in this use case is used to validate the framework.

1. INTRODUCTION

The combined and integrated use of heterogeneous software systems, to map processes along the value chain, is made possible through the use of a so-called Enterprise Application Integration (EAI) framework. EAI combines planning process oriented software systems and process descriptions to a single system. To connect the different software systems, the actual source code does not need to be changed. Instead, the interconnection is realized through the use of adapters. This enables the operator to use the software systems either as an individual program or as a part of a program chain via a single man-machine interface. The utilization of program chains allows the mapping of simulated processes to the corresponding business processes.

Presently, EAI is primarily used in manufacturing companies to depict recurring, semi- or fully-automated business processes. However, existing frameworks do not consider the integration of software systems that are found in the planning areas of materials and processing techniques. Thus, during the manufacture of a commodity, the depiction of a business process is neglected. Consequently, implications on the overall process and other important details derived from the production process are lost. If the aim is to picture the production of a commodity from raw material to a finished product in order to identify the majority of implications, the contemplation of the business process is not sufficient. In fact, the realization of this aim requires a continuous modelling of the process from the raw material to the finished product.

Simulations already exist for most of the manufacturing processes in the production of goods. These include, for example, welding, forming or heat treatments. Those simulations are usually isolated solutions, which have no common interfaces or data formats. Right now, existing systems do not address the interconnection of these simulations. As a consequence, simulation chains modeling manufacturing processes as part of virtual production are not adequate, because implications e.g. from the first simulation on following simulations are not considered. Therefore, a framework is needed to facilitate the interconnection of the simulations to simulation chains.

In this paper a framework is presented, which is capable of interconnecting heterogeneous distributed simulations to form simulation chains. This contribution focuses on interweaving the syntactic and semantic incompatibility of the previously mentioned simulations. The framework uses an ontology to match the different representations of names and the underlying concepts as well as relationships between the concepts. The concepts and relationships are stored in a strongly abstract manner in a top level ontology. Domain specific ontologies are used for the representation of concepts and relationships of certain simulations. The validation of the framework is established by virtually representing the manufacturing process of a Line-Pipe.

2. PROBLEM

A multitude of manufacturing steps in the production process of goods are described by numerical simulations. Today an examination of a production process is based on singular consideration of the manufacturing steps without interlinking. This results in the problem that the single results of the simulations are not directly set in context of the entire production process. Figure 1 shows the production process of a Line-Pipe as an interlinkage of multiple manufacturing steps.

The production process consists in detail of a series of heat treatments, forming processes, machining and joining techniques. Each of these production steps is represented by a numerical simulation. The models for each domain (e.g. joining) used in the simulations are based on corresponding expert knowledge. Usually, these simulations are isolated applications that do not have common interfaces and data formats. In addition, the simulations calculate with different physical scales: The metal forming, machining and the joining simulations examine macrostructure changes, while the heat treatment simulation process changes the microstructure, e.g. modifications of material properties. In existing planning processes the interconnection of simulations to simulation chains to map a whole production process, covering diverse scales and knowledge domains, is not considered sufficient. Therefore it is necessary to combine the simulations context sensitive. To apply simulations interconnected as simulation chains, an integration tool is needed that realizes the interlinkage of the various simulations [1].

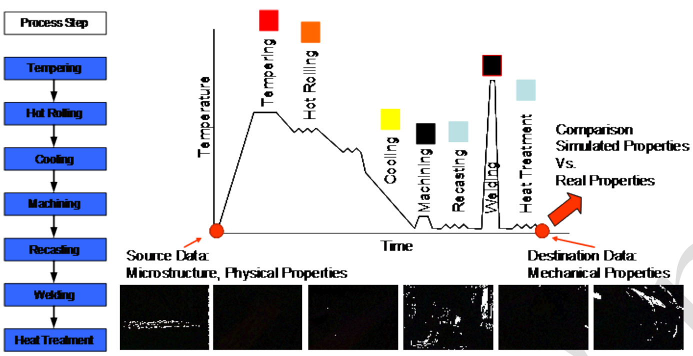

Figure 1: Production process of a Line-Pipe

EAI is developed to establish application interconnection on the level of business processes. In the following section (section 3) the current state of the art of EAI frameworks is presented. Subsequently, a tool for data integration is introduced (section 4). The tool enables the user to realize the interconnection of heterogeneous numerical simulations. The production process of a Line-Pipe is used for the validation of the introduced data integration tool (section 5). The paper concludes with a summary and outlook on further development opportunities.

3. STATE OF THE ART

EAI can be understood as a comprehensive concept that includes a complete set of business processes, management functions and organizational interactions for performing, controlling and monitoring. As a holistic process, EAI designs seamless high-agile processes and organizational structures that match the strategic and economic concept of a company. Systems in which EAI concepts are used are characterized by integrative, progressive and iterative cycles of technology, labour force, knowledge and operational processes usage [2]. Observing information technology systems used for the implementation of EAI, the term becomes more clarified and concrete: EAI is understood as a software tool for integrating heterogeneous systems [3].

Common EAI frameworks consist of the components meta database, middleware, adapters, message management and process management (see figure 2) to provide the claimed functionality [4]. Important references concerning the EAI modelling are given in the works of Linthicum, Ruh, Cummins, O'Rourke and Whitten [5-9].

- The middleware is designed to manage adapters and resources and to provide auxiliary services.
- The adapters realize the connection between the different to be integrated applications and the middleware. Two types of adapters are used, a static (fixed implementation) and a dynamic (configurable) adapter. Both should overcome the incompatibilities that result from both the syntactic and the structural heterogeneity of the applications. The static adapters are developed and used in a context that does not change. The dynamic adapters are used in a changing context and have to be reconfigured depending on the use case.
- The meta database is the central storage of information concerning the distribution of components. Information about the safety parameters, responsibilities, technological infrastructure, communications patterns, transformations, rules and logic for processing messages, architecture and design are stored and managed.
- The information management provides transformation and synchronization services and ensures the transactional of transformation operations. The information management component overcomes on the one hand the constraints of syntactic and structural heterogeneity and on the other hand the semantic heterogeneity.
- The process management controls and administers process modelling, process control and process steering. Running and interruptible semi-automated business processes are supported by the process management. Furthermore, the process management takes over the process monitoring and reporting [4].

Current EAI Framework solutions are presented in the following. Two proprietary (Oracle and IBM) and two open-source frameworks (JBoss, Open Adaptor) will be compared. The selection is not a substantive review but based on the wide distribution of the frameworks. Table 1 gives a brief overview of the mentioned EAI frameworks.

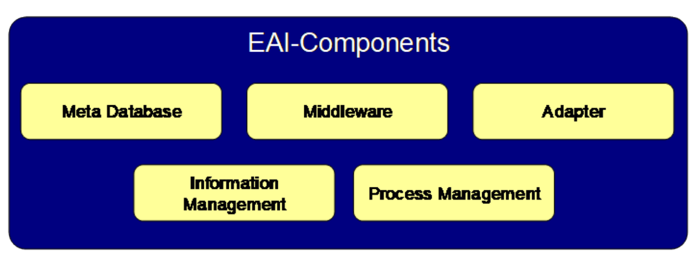

Figure 2: EAI components

Oracle Application Server Interconnect

The EAI Framework Application Server Interconnect is developed by Oracle. It uses a XML-based common data schema and model for the application integration. The applications that should be integrated are connected to the framework by using an integration logic. This logic creates integration points that are stored in a meta database and that are linked to the common data model. The integration of the respective application happens event driven. Here, the applications are assigned to an integration point defined by an event. Whereby, the overall process can be represented via the EAI framework by using the interconnected applications [10].

IBM WepSphere Product Suite

The IBM WebSphere Product Suite provides a collection of tools such as Message Broker, Event Broker, Message Queue and Process Server for linking applications. This product uses a common data schema and model that is based on XML as well. To realize connections on the data layer via protocols such as FTP, HTTP, etc. the suite provides adapters. Graphical programming is used for the user interface. There configurable blocks can be linked in order to program an application integration [11].

JBoss

Also JBoss uses XML messages for communication within the framework. The EAI framework is developed in Java Open Source. Applications are integrated into the framework via adapters. To ensure the communication along the described process JBoss compliant XML messages are generated by the respective adapters. For links to resources such as Internet, databases, etc. connectors are implemented [12].

OpenAdaptor

OpenAdaptor does not provide a framework for application integration, but individual adapters, with which isolated applications can be interconnected. Provided standard adapters can be configured via XML for the integration of a particular application. Java objects are used for data exchange between applications. These are implemented in the adapters. The scheme in figure 3 shows the coupling of two applications with OpenAdaptor using a reading, a writing and a processor component [13].

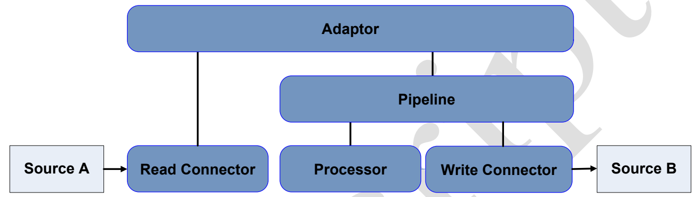

Figure 3: OpenAdaptor interconnection scheme

The main objective of the presented frameworks and solutions for application integration is the interconnection of the applications along a business process and the provision of an integrated solution. Here XML is often used to ensure a common data schema and model map. For the manufacturing process outlined in Section 2 and due to the large amount of structured finite element (FE) data, XML is not appropriate as base for a common data schema or model, because of the slower processing speed as a FE optimized data format like e.g. VTK [14]. In addition, EAI frameworks are designed to achieve semantic linkage to applications of the same or a related knowledge domain [15]. For the use case described in section 5, it is necessary to realize a semantic integration along many knowledge domains. In the following section the designed Data Integrator for cross-domain semantic interconnection is presented. The Data Integrator is developed at the ZLW/IMA at RWTH Aachen University.

Table 1: EAI Frameworks

EAI Framework	Proprietary or Open Source	Data Scheme / Model	Miscellaneous	FE Data
Oracle Application Server Interconnect	Proprietary	Common XML based data model	Oracle BPEL PM, Oracle Enterprise Bus, etc. extensions	No
IBM WepSphere Product Suite	Proprietary	Common XML based data model	Message Broker, Event Broker, Message Queue, Process Server, etc.	No
JBoss	Open Source	JBoss conform XML Message system	JBoss Application Server and JBPM extensions	No
OpenAdapter	Open Source	Java Objects		No

4. DATA INTEGRATION

The developed Data Integrator uses for the application interconnection the simulations input and output as files. The outputs of the applications as well as additional manual inputs are integrated via an Extract-Transform-Load-Transform process (ETLT process) into the common data storage. The required input data for an application is extracted with an Enrich-Extract-Transform-Load process (EETL process) from the common data storage [16]. Figure 4 shows schematically how two simulations will be combined to an integrated solution. The common data storage is realized by using a database. This has to be treated analogous to the data schemas and models of the frameworks presented in section 3 [17]. Among others the ETLT and EETL processes take over the tasks of the adapters and connectors that are mentioned in section 3. In the following, the functioning and the main objective of these two processes will be explained in detail.

In the first step of the ETLT process the data of sources present will be extracted (extract). Extraction sources can be files or input via a human-machine interface. Then, the extracted data is transformed into the data model that is represented in the database (Transform). This implies for the usage of finite element data, that the node, element and attribute information has to be indicated and named. Therefore a semantic mapping of the meaning of the identifiers is required. After this, the data is stored in the database (Load). The successful validation of the integrated data in a post-processing is the conclusion of the ETLT process.

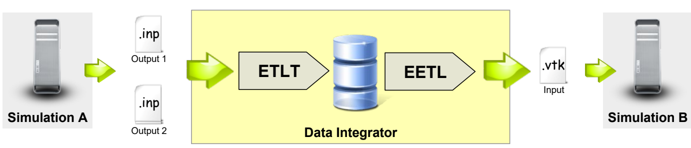

Figure 4: Data integration scheme of the Data Integrator

Via the EETL process data can be extracted from the database by using a series of sub-processes for a source. The first sub-process will either convert the data in the required format or generate the required data out of existing data (Enrich). The functionality of the enrich process is shown in figure 5.

Data as temperature, strain, stress, cross-sectional area and length of a component is stored in the database. The target source of the example described in figure 5 requires the temperature in K, the modulus of elasticity and the spring constant. The temperature can be migrated directly, but the modulus of elasticity and the spring constant has to be generated by using transformations. After that, the data are to be extracted from the common data storage (Extract), to be subsequently brought into the required structural form (Transform). The last sub-process is the writing of the required input file (Load) for the target source. The meanings of each field stored in the database are used for the data mapping. The meanings are related to the corresponding application. Therein the processes for application integration used by the Data Integrator are described. In the following, a brief demonstration of the integration process of heterogeneous numerical simulations is given, where the continuous manufacturing process of a Line-Pipe will be simulated as a use case.

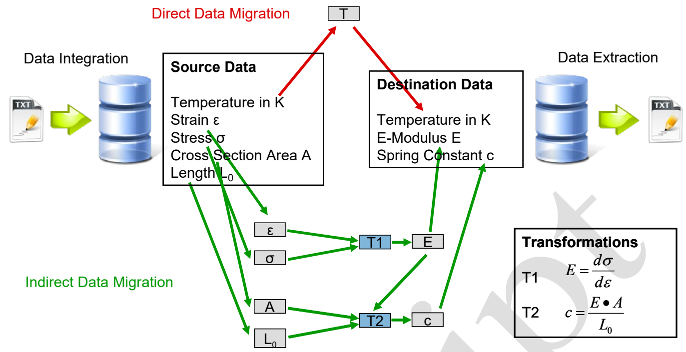

Figure 5: Enrich process

5. USE CASE

For the validation of the Data Integrator presented in section 4, the simulation of the manufacturing process of a Line-Pipe (see figure 1) as use case is realized. Here, simulations which consider changes at the macro level and microstructure simulations are linked to a simulation chain. The application flow is to be automated. All input data are entered either on initialisation or generated during runtime from the available input and output data by the Data Integrator. After every process step on the macrostructure level a microstructure simulation is performed. The results of the microstructure simulation are used by the macrostructure simulations as input data. A homogenization application comes into operation to condition the microstructure simulation results for further computing by the macrostructure simulations. Also, the simulations which are developed as stand-alone solutions have no common interfaces. Furthermore, input and output of the simulations differ in syntax (differences in the technical presentation of information), structure (differences in the structural representation of information) and semantics (differences in the meaning of used terms and concepts). To simulate the entire manufacturing process five applications are used in the following order (see figure 1 and table 2): The first software CASTS (developed by ACCESS e.V.) is used to simulate tempering. Then the forming simulation LARSTRAN (developed by the Institute for Metal Forming (IBF), RWTH Aachen University) is used to present the hot rolling process. The following cooling process and the machining for weld prep are simulated again with CASTS. The forming of the metal sheet into a tube is calculated with ABAQUS, a development of Dassault. The Institute of Welding and Joining (ISF) of the RWTH Aachen University provides a welding simulation called SimWeld to represent the penultimate process step. The final step in the simulated production process of the Line-Pipe manufacturing is the expansion (heat treatment), which again is represented by the application CASTS.

Table 2: Line-Pipe Manufacturing Process

Process Step No.	Software	Process Step	Publisher
1	CASTS	Tempering	ACESS e.V.
2	LARSTRAN	Rolling	IBF, RWTH
3	CASTS	Cooling	ACESS e.V.
4	CASTS	Machining	ACESS e.V.
5	ABAQUS	Recasting	Dassault
6	SimWeld	Welding	ISF, RWTH
7	CASTS	Heat Treatment	ACESS e.V.
8	MICRESS	Microstructure Analysis	ACESS e.V.

After each of these steps a microstructure simulation is performed with the software MICRESS (ACCESS e.V.) to create better input data for the macrostructure simulations [18]. With the application HOMAT (ACCESS) the microstructure data is homogenized [19] for the use at macrostructure level.

The main problem during the realization of the automated simulation chain was the identification of the relevant data, which has to be passed from one simulation to the next because not all information is important for all simulations. But the used Data Integrator [1] was able to provide the needed data.

6. CONCLUSION AND OUTLOOK

The Data Integrator can be used automatically in conjunction with a middleware [20, 21]. Then the Data Integrator reads the input and output files of the previously mentioned simulations. Additional it understands and generates new files according to the schemes presented in figures 4 and 5. Therefore, all parameters that can not be generated by the process must be known in addition to the input file of the first simulation (CASTS – tempering).

In this paper a tool for integrated automated interconnection of applications was presented. The Data Integrator is based on the general concepts of EAI [4] and was validated against the simulated manufacturing process of a Line-Pipe. It represents an important element in the realizing process of a virtual production. In addition to the virtual representation of factories and plants the Data Integrator enables a clear and step by step presentation of the manufacturing processes. For example different simulation models can be linked to an overall process across scales by using the Data Integrator.

A next step towards virtual manufacturing is the integration of all simulations that are used in the design and manufacturing of products. This means that not only machinery but also process simulations and factory planning tools are taken into account, which results in the following key challenges: integration of other knowledge domains along the vertical axis and extending the opportunity for additional mappings of syntax, structure and semantics. The long term objective is the establishment of vertical integration of the simulations next to the horizontal in order to enable the user to get an integrative view from raw materials through the material processing up to the manufacturing factory.

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