Prototype of a Federative Factory Data Management for the Support of Factory Planning Processes

Christian Mosch, Reiner Anderl, Antonio Álvaro de Assis Moura and Klaus Schützer

Abstract—Due to short product life cycles, increasing variety of products and short cycles of leap innovations manufacturing companies have to increase the flexibility of factory structures. Flexibility of factory structures is based on defined factory planning processes in which product, process and resource data of various partial domains have to be considered. Thus factory planning processes can be characterized as iterative, interdisciplinary and participative processes [1]. To support interdisciplinary and participative character of planning processes, a federative factory data management (FFDM) as a holistic solution will be described. FFDM is already implemented in form of a prototype. The interim results of the development of FFDM will be shown in this paper. The principles are the extracting of product, process and resource data from documents of various partial domains providing as web services on a server. The described data can be requested by the factory planner by using a FFDM-browser.

Keywords—BRAGECRIM, Factory Planning Process, Factory Data Management, Web Services

I. INTRODUCTION

INCREASING the flexibility of factory structures is one of the key factors to increase the market participation. One possibility of realizing an increasing flexibility is the optimization of information, innovation and quality management. Frequently manufacturing processes have a limited ability of reacting in a required fast, flexible and proactive way [2]. The IT tools of the digital factory give possibilities of increasing flexibility but have also several deficits. The main deficit is the high number of IT tools itself and the defective harmonization between themselves [3, 4].

Harmonization and integration on IT-tool-level is one challenge. Another challenge is the harmonization and integration on domain-level. In factory planning processes, several domains like product development, resource planner, or manufacturing process planner are participating. The command of the complexity in product development [5, 6] as well as in factory planning [7, 8] needs a holistic data management. This holistic data management has to consider product planning, product design, production planning, material purchasing, machine providing, manufacturing, usage, repair and recycling [9, 10]. The harmonization and integration on IT-tool-level and domain-level resulting in a reduction of frequency of innovation are faced up in research

as part of the FedMan-project within the BRAGECRIM-initiative.

II. BRAGECRIM AND FEDMAN

BRAGECRIM is an acronym for "Brazilian-German Collaborative Research Initiative on Manufacturing Technology" and is a research and cooperation network between more than 30 universities and research institutions in Brazil and Germany. The cooperation network has to merge and complement research activities in basic research and in transfer and application. BRAGECRIM is funded by

- DFG (Deutsche Forschungsgemeinschaft, Germany),
- CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Brazil),
- FINEP (Financiadora de Estudos e Projetos, Brazil) and
- CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil).

Within BRAGECRIM 16 cooperation projects between universities and research institutions from Brazil and Germany exist. One of these projects is the cooperation project "FedMan" and deals with the topic "Federative Factory Data Management (FFDM) based on Service Oriented Architecture (SOA) and Semantic Model Description on XML and RDF". Cooperating partners are the Department of Computer Integrated Design (DiK) at Technische Universität Darmstadt in Germany and Laboratory for Computer Application in Design and Manufacturing (SCPM) at Methodist University of Piracicaba in Brazil.

III. FACTORY PLANNING PROCESSES AND ITS DEFICITS

Solving the deficits in factory planning processes is core of FedMan. The increasing usage of isolated IT tools results in deficits of data holding. As described before, harmonization and integration on IT-tool-level and on domain-level are big challenges, which have to be faced up within FedMan. Within factory planning processes a huge amount of data results from several isolated IT tools as well as from various participating partial domains with its specific data bases. This facts result in redundant, inconsistent and heterogeneous data holding. By considering levels and types of factory planning processes these deficits exponentiate (Fig. 1).

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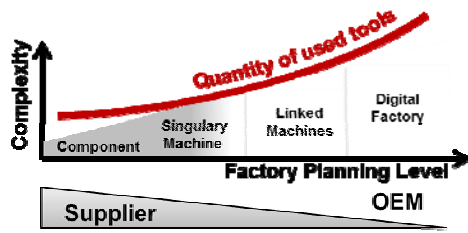Vol:5, No:3, 2011

Fig. 1 Quantity of used tool in factory planning level
[11, 12, 13]

Factory planning processes can be divided into component, machine, line, factory and supply chain level [11, 12, 13]. Further a correlation of increasing level of factory planning processes and an increasing quantity of existing and involved IT tools exists. These increasing quantity of IT tools result in an increasing quantity of singular data holding.

An analog deficit exists in differencing of types of factory planning processes. In general factory planning types are new planning, replanning and rationalization [14].

In new planning building up new factories for manufacturing new products is focus of interest [15]. New data from existing or new IT tools are generated. At the beginning of the factory planning process integration of IT tools and a reduction of redundant, inconsistent and heterogeneous data holding prior value can be placed.

In replanning an existing factory will be adapted to a changed or new product. This results mostly in new acquisitions or restructuring of resources [15]. Based on partial new acquisitions some new data are generated by new IT tools. Due to an existing factory databases already exist in the form of product, process and resource data which are generated by existing isolated singular IT tools. Results are difficulties in migration to new (integrated) IT tools.

In rationalization an existing factory has to be optimized with the aim to increase efficiency in manufacturing. Usually rationalization is realized with existing resources and minor changes factory structure [15]. No new acquisitions and thus no new generated data resulting from new IT tools have to be considered. Mostly existing product, process and resource data generated by existing isolated singular IT tools have to be managed. Challenge is the managing of difficulties in migration of existing data.
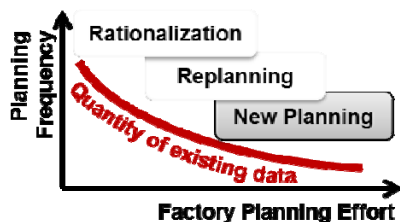

Fig. 2 Quantity of existing data in factory planning types [16]

In replanning and rationalization of factory structures a high quantity of existing data generated by isolated singular IT tools exists (Fig. 2). Taking into account the increasing number of involved IT tools and the levels of the factory planning process core of FedMan project can be described in one sentence as follows:

"Core of FedMan is the integration of existing, singular and isolated IT-tools in the factory planning process based on a Federal Factory Data Management (FFDM)".

IV. ARCHITECTURE OF FEDERATIVE FACTORY DATA MANAGEMENT (FFDM)

In general among three integration strategies of IT tool in factory planning processes can be differed. First, IT tools can occur in an isolated and distributed way. This possibility of integration is called as an indirect coupling of IT tools. Autonomy of IT tools within respective area of responsibility is maintained.

The opposite possibility of integration is a direct coupling of IT tools. IT tools do not keep their autonomy but are harmonized with further IT tools within planning processes.

Keeping advantages of autonomy and harmonization can be realized by a third possibility of integration which is called as a loosely coupling of IT tools or Federation. Federation can be described as an encapsulated integration with a maintaining of partial autonomy [17].

Advantage of Federation is the flexibility of IT infrastructure e.g. in case of change or update of IT tools [18].

The concept of federated IT tools and their databases requires a communication between isolated singular IT tools and their autonomous databases. In development of FFDM this communication is realized by service oriented architecture (SOA) based on web services. SOA is currently the most favored and promising approach and can be described with following characteristics [19]:

- SOA is process-controlled and –driven. Integration of factory planning processes is main target.
- SOA is independent. No specific IT technology or environment is required for implementation of SOA. Web service technology is chosen as an independent possibility for implementing SOA.
- SOA is extensible. Enlarging SOA with further IT tools by creating new web services is possible at any time.
- SOA leads to an increasing connectivity in heterogeneous environments (processes, data, and applications). The interconnection of various existing heterogeneous IT systems will be improved.

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The SOA of FFDM builds upon four layers (Fig. 3 shows the architecture of FFDM):

- Front-end layer as a presentation layer in form of a browser,
- Federation layer as a communication layer realized by SOAP (Simple Object Access Protocol),
- Interface layer by web services with its implemented functions and
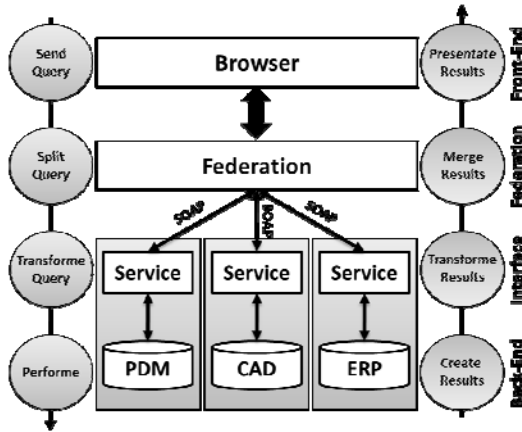- Back-end layer with domain specific IT tools like CAD, CAM or ERP.

Fig. 3 Architecture of FFDM

Defined web services with its implemented functions are linked by protocol interfaces with the front-end of the user. The front end of the user in this project is realized in the form of a browser (input form).

The protocol interface in federation layer between browser and services is SOAP (Simple Object Access Protocol). SOAP is based on XML (Extensible Markup Language) and is developed for exchanging basic messages between applications.

The defined web services with its functions (e.g. parse data, envelop to SOAP, send SOAP) at interface layer are accessible by web services at a web server. These web services are implemented and provided.

Data resulting from different domain specific IT tools (e.g. CAD, CAM or ERP) at back-end layer are posted in form of XML to the web server by a release function within domain specific IT tools. With each release within a domain specific IT tool, files get uploaded via FTP (File Transfer Protocol) in form of XML to defined web servers. These XML files can be processed by implemented web services online in real time after requesting from browser.

V. IMPLEMENTED FFDM

Starting describing the implementation of the concept beginning from the front-end layer, a browser is created in form of a client program. The browser is connected to web services following Web Service Definition Language (WSDL). The connection is realized with SOAP technology. SOAP-

messages can transfer data and metadata about processes, products and resources.

A. FRONT-END

The task of the browser is to link and to structure product, process and resource data and metadata. The realized visualization of the relations and links of product, process and resource data in form of a matrix is shown in Fig. 4.
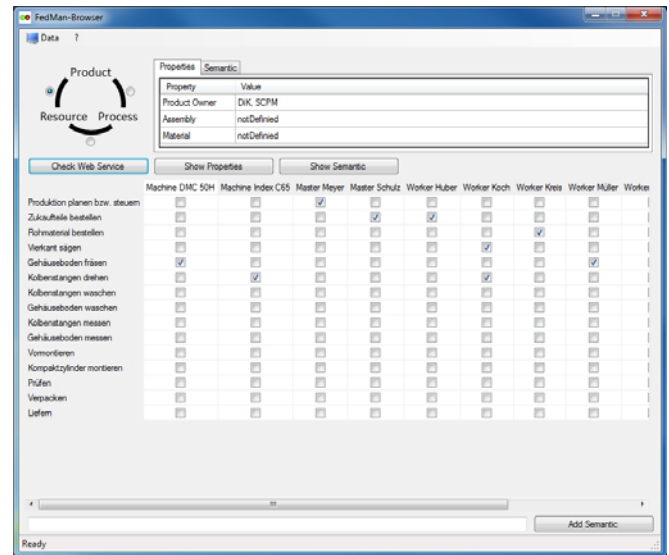

Fig. 4 Implemented FFDM-browser

In detail Fig. 4 shows a matrix of process and resource data on factory level. Process data on factory level are data related to a manufacturing operation like: milling, drilling, sawing, ordering raw etc. Additional metadata about a concrete process can be machining time, set-up time, etc. These metadata are shown in the properties-tab of the FFDM-browser. Resource data on factory level can be concrete machines or workers. Process and Resource data are results from different IT tools and relations and links are not obviously. Thus views of relations and links between processes and resources are important for the FFDM-browser. In this described matrix process–resource relations of processes on factory level and its used resources on factory level like machines or workers are visualized (compare to Fig. 4). Combined metadata like the machining time of a defined resource can be queried.

To fulfill the possibilities of variant management, various variants of factory structures can be chosen. Products, processes and resources have specific numbers of variants. These number and type of variants are implemented as web services. Before querying specific product, process and resource data from server, concrete variant of interest must be pre-requested.

The described different factory planning level machine, line, factory and supply chain level [11, 12, 13] are considered in the implemented FFDM-browser. Before querying data of different variants of products, processes and resources, reference of available data to planning level will be pre-requested (Fig. 5). As a result of pre-request of factory

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planning level referenced to variants of product, process and resource data, concrete web services can be queried for values.
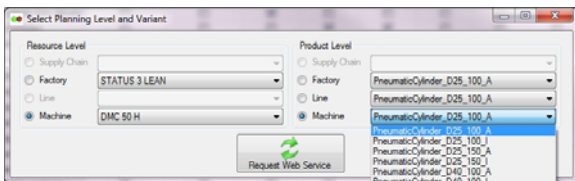

Fig. 5 Considered Factory Planning Level and Variant-Management in FFDM

B. Data Request with SOAP

SOAP is a protocol for exchanging messages based on XML. The requirement of a SOAP-message representation is an envelope. Within this envelope, a body-element is required; a header-element is optional. Within the body-element, data and metadata from various domain-specific IT tools can be included. Included metadata are author, date, kind of application, etc. Included data are representative data parsed from XML-document on a web server resulting from domain-specific applications like CAD, PDM or ERP. These XML-documents can be parsed by functions of web services. Every implemented web service provided on a web server has implemented functions to parse XML-documents, extract queried data, envelope the parsed and extracted data to a SOAP-message and send this SOAP-message back to FFDM-browser. FFDM-browser interprets received SOAP-messages and presents contents like product, process and resource data (Fig. 6).
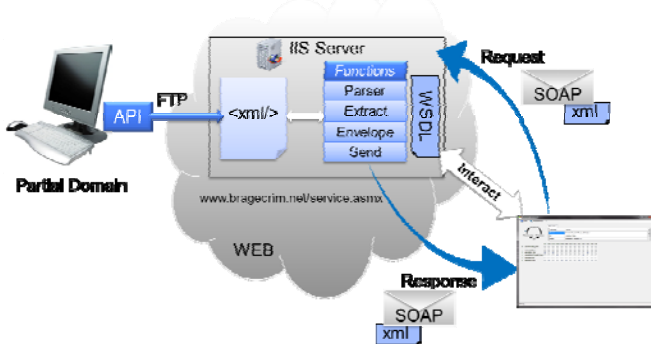

Fig. 6 Implemented FFDM web services

To realize an interaction between FFDM-browser and web services and to give FFDM-browser the possibility to interpret SOAP-messages, a WSDL (Web Service Definition Language) must exist. WSDL acts as a schema for FFDM-browser and web service. Following WSDL SOAP messages will be created and interpreted.

C. Data-providing with XML

Results generated by applications have to be described as data independent from native documents. Due to this, XML-format was chosen to describe product, process and resource data in neutral and open way. XML must not be seen as a master solution, but as one possibility. Another possibility of

describing product data in a neutral way is STEP. Both have in common the possibility of parsing and extracting data. In used tools like CAD or CAM, release functions are implemented, which export and describe data in XML and upload it directly to a chosen web server by FTP (File Transfer Protocol). By this solution only the newest version of product, process and resource data is available for factory planners. Possibilities of managing versions have to be implemented in further developments.

VI. CONCLUSION

The described currently situation in factory planning processes gives a rough overview of the challenges for manufacturing companies. Factories must be integrated into product creation process as independent complex systems. Within factory planning processes various domains like product development, production management and process planning are participating. Generated product, process and resource data by these domains result from a sum of isolated IT tools which have to be integrated at data level. Theses described challenges are faced up by the project "FedMan" funded by DFG (Germany), CAPES, FINEP and CNPq (Brazil). Integration is realized by a FFDM based on SOA and web services. Browser of FFDM and basic functions of web services are implemented. Semantics based on RDF (Resource Description Language) to represent knowledge of the factory planner has to be considered in further FFDM development.

Goal of the concept of FFDM is to meet the challenges of factory planning processes. One of the key-challenges is the integration of isolated, domain-specific IT tools and generated domain-specific partial models. This integration is based on a document independent factory structure description linked with factory defining metadata

Advantage of the concept is to use existing technologies (web services, SOAP, XML, RDF) and the integration of FFDM into existing IT environments. Existing domain-specific IT tools and processes can keep their autonomy combined with the integration of the generated data. Goal is the improvement and harmonization of factory planning processes considering the costs for investment for industrial companies.

REFERENCES

[1] Anderl, R.; Rezaei, M.: Federative Factory Data Management – An approach based upon Service Oriented Architecture (SOA), Book, International CIRP Conference - Digital Enterprise Technology, Setúbal, Portugal, 2006.
[2] Wiendahl, H.-P.; Nofen, D.; Klußmann, J.-H.; Breitenbach, F.: Planung modularer Fabriken - Vorgehen und Beispiele aus der Praxis. München, Wien, 2005.

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International Journal of Computer and Information Engineering
Vol:5, No:3, 2011

[3] Schack, R.: Methodik zur bewertungsorientierten Skalierung der Digitalen Fabrik. Dissertation der TU München. München, 2007.

[4] Eißrich, R.: Die Vernetzte und integrierte Planung durch die digitale Fabrik. In: Intelligenter Produzieren 2005/01, Frankfurt a. M., 2005.

[5] Langenberg, L.: Firmenspezifische Wissensportale für die Produktentwicklung, Book, Shaker Verlag, Aachen, Germany, 2001.

[6] Jania, T.: Änderungsmanagement auf Basis eines integrierten Prozess- und Produktdatenmodells mit dem Ziel einer durchgängigen Komplexitätsbewertung, Dissertation of the University of Paderborn, Paderborn, Germany, 2004.

[7] Aggteleky, B.: Fabrikplanung – Werksentwicklung und Betriebsrationalisierung, Book, Carl Hanser Verlag, München, Germany, 1987

[8] Kettner, H.; Schmitt, J.; Greim, H. R.: Leitfaden der systematischen Fabrikplanung, Book, Fachverlag Leipzig, Leipzig, Germany, 1984.

[9] Eißrich, R.: Die Vernetzte und integrierte Planung durch die digitale Fabrik. In: Intelligenter Produzieren 2005/01, Frankfurt a. M., 2005.

[10] Anderl, R.: Skript zur Vorlesung Virtuelle Produktentwicklung A

[11] Ciupek, M.: Beitrag zur Simulationsgestützten Planung von Demontagefabriken für Elektro- und Elektronikaltgeräte. Dissertation, TU-Berlin, Berlin, 2004.

[12] Feldmann, K. / Reinhart, G.: Simulationsbasierte Planungssysteme für Organisation und Produktion. Springer-Verlag, Berlin Heidelberg, 2000.

[13] Wuttke, C. C.: Mehrfachnutzung von Simulationsmodellen in der Produktionslogistik. Dissertation, Universität des Saarlandes, Saarbrücken, 2000.

[14] Grundig, C.-G.: Fabrikplanung. Planungssystematik - Methoden – Anwendungen. Carl Hanser Verlag, München, 2006.

[15] Rezaei, M.: Konzeption eine Fabrikinformationsmanagements auf Basis von postrelationalen Datenbanken – Ein Beitrag zur Unterstützung von Concurrent und Simultaneous Engineering in der integrierten Prozessgestaltung. Dissertation der TU Darmstadt, Shaker Verlag, Aachen, 2010.

[16] Abele, E.; Stroh, C.; Anderl, R.; Piechnick, M.; Kempf, K.: Simulation in machine tool development process. In: International PACE Forum Digital Manufacturing 2005. Darmstadt, 2005.

[17] Abeln, O.: Innovationspotentiale in der Produktentwicklung: Das CAD-Referenzmodell in der Praxis. Teubner Verlag, Stuttgart, 1997.

[18] Fröhlich, A.: Integration des Prüffeldes in die virtuelle Produktentstehung. Dissertation der TU Darmstadt, Shaker Verlag, Aachen, 2003.

[19] Abramovici, M.; Bellalouna, F.: SOA-Architecture for the Integration of Domain-Specific PLM Systems within the Mechatronic Product Development, Paper, Proceedings of the 7th International Symposium on Tools and Methods of Competitive Engineering, TMCE 2008, Izmir, Turkey, 2008.

Christian Mosch joined a position as a Research Assistant at the Department of Computer Integrated Design (DiK) in October 2008. As a research work he deals with a DFG promoted BRAGECRIM-Initiative with the topic "Federative Factory Data Management based on SOA and Semantic Model Description on XML and RDF for Manufacturing Products" (FedMan).

e-mail:mosch@dik.tu-darmstadt.de

Reiner Anderl was vice-president of Technische Universität Darmstadt until December 2010 and is head of the Department of Computer Integrated Design at the Faculty of Mechanical Engineering at Technische Universität Darmstadt.

Antonio Álvaro de Assis Moura is doing his Ph.D. at Methodist University of Piracicaba. In 2010 was in an exchange program at Technische Universität Darmstadt within a CAPES promoted BRAGECRIM-Initiative with the topic "Federative Factory Data Management based on SOA and Semantic Model Description on XML and RDF for Manufacturing Products" (FedMan).

Klaus Schützer is professor at Methodist University of Piracicaba and head of the Laboratory for Computer Application in Design and Manufacturing at the Faculty of Engineering, Architecture and Urbanism.