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Data Integration Framework for Heterogeneous System Landscapes within the Digital Factory Domain

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Abstract

Due to shorter product lifecycles and a rising complexity of the products more and more enterprises consider using the *Digital Factory*. The *Digital Factory* is an IT system capable of digitally planning, controlling and optimizing all resources and activities related to a product which are performed beginning with product development and ending in the order processing – prior to the start of the real production of the product. Today the companies' system landscapes within the *Digital Factory* domain are usually very heterogeneous with limited interoperability of the applications in use. However data integration is crucial for a successful implementation of the *Digital Factory*. This article provides a reference model based framework consisting of three main steps and ten sub-steps. It can be applied by companies in order to optimize and integrate such heterogeneous system landscapes.

Keywords: Digital Factory; Reference Model; Data Integration; System Landscape

1. Introduction

Today industrial enterprises are facing shorter and shorter product lifecycles in combination with a rising complexity of their manufactured products [5]. These changing basic conditions require enterprises to enhance their planning efficiency as well as their planning quality. One approach to reach these goals is to introduce the *Digital Factory*. The *Digital Factory* is defined as an IT system capable of digitally planning, controlling and optimizing all resources and activities related to a product which are performed beginning with its development and ending in the order processing – prior to the start of the real production of the product [9].

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Prior research on this topic has shown that it is crucial for a successful implementation of the *Digital Factory* to integrate all involved software applications - preferably while using a single common data repository [1,8,13]. However according to [10] there are currently three main factors which preclude such a cross process data integration:

- Current software system landscapes are very heterogeneous with a high number of isolated solutions
- Most of the software solutions within the *Digital Factory* domain only have limited to no interoperability at all
- There is no standardized data exchange format existent within the *Digital Factory* domain

In this paper we will introduce a reference model based framework. It can be applied by companies trying to achieve cross process data integration within a heterogeneous *Digital Factory* system landscape.

2. Related Work

There is some research available on the integration of software solutions for the *Digital Factory*. The ADiFa project, a web service based concept, has been proposed which aims at enabling the exchange of planning data in heterogeneous IT-environments like those within the *Digital Factory*[14]. Another project identifies and evaluates five different design patterns for data integration in complex application landscapes [15]. In [11] a concept for an integration of enterprise resource planning systems with product data management systems is defined. Additionally there are some approaches available which intend to provide a data exchange platform based on some specific exchange formats like STEP [2,12,17] or AutomationML[6,7].

However, all of those concepts do follow a very technical approach towards the problem, describing how interfaces between two software solutions could be set up in order to exchange data in an optimized way. It is also noticeable that none of the research has yet focused on providing a procedure or process model which could give practical guidance to a company which is having problems with its complex and heterogeneous application landscape in the context of the *Digital Factory* and wants to transform it into an integrated and redundancy-free landscape.

3. Data integration approach

In this chapter we will first describe the initial situation a lot of companies using the *Digital Factory* are facing today. We will then show an improved target system landscape and introduce a reference model which can be applied by such companies thus improving their system landscapes from a data integration point of view in order to reach this target landscape.

Today's system landscapes within the *Digital Factory* domain are usually very heterogeneous [3]. They are using a high number of different applications, each only responsible for a limited amount of tasks [4]. Since the tasks they support are mostly interconnected, data needs to be exchanged between these applications. However many of the applications being used only have limited interoperability [14]. This leads to a system landscape with many point-to-point data flows between the applications, and lots of individual or even manual interfaces between them. Additionally those landscapes have grown over time and are often not documented very well. As a consequence, most of the time it is only known that two applications are connected, but the direction or the contents of the data flows are unknown. This means that in such a landscape extensive maintenance efforts are necessary and the implementation of changes is a very complex process (Fig).

The target landscape on the other hand is an integrated landscape in which a central data management system is employed (Fig.). All applications used within the *Digital Factory* domain solely communicate with this central system. All data flows are documented and flow direction as well as the content of the data flow is known. The communication itself is conducted using a neutral exchange format which leads to a high standardization of the interfaces. Such a landscape has the following advantages: one single communication partner per application, changes induce less effort, reduced data redundancy, improved transparency and standardization of the interfaces.

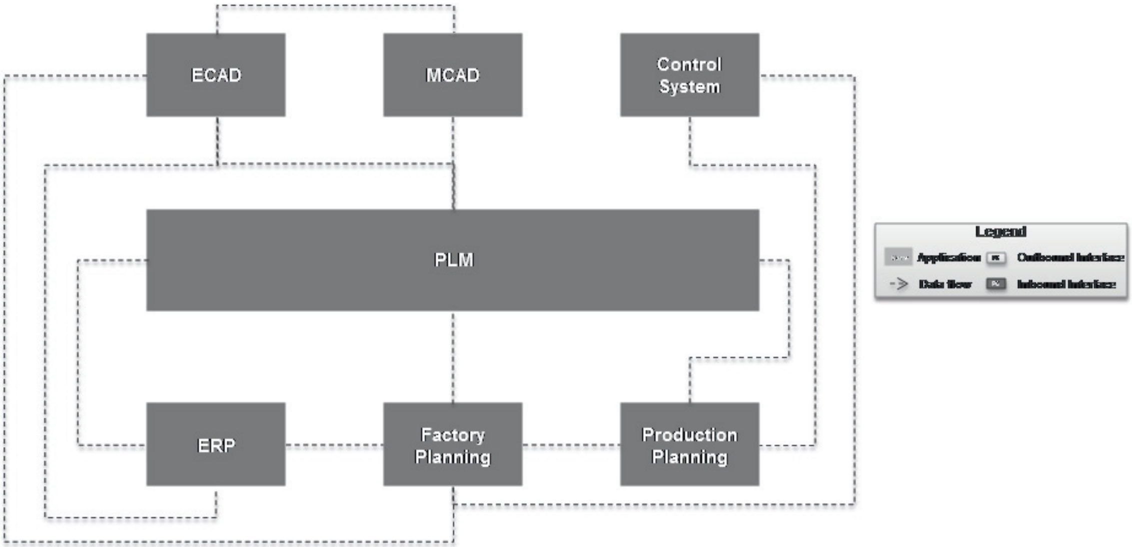

Fig. 1. Heterogeneous sample as-is system landscape within the *Digital Factory* domain.

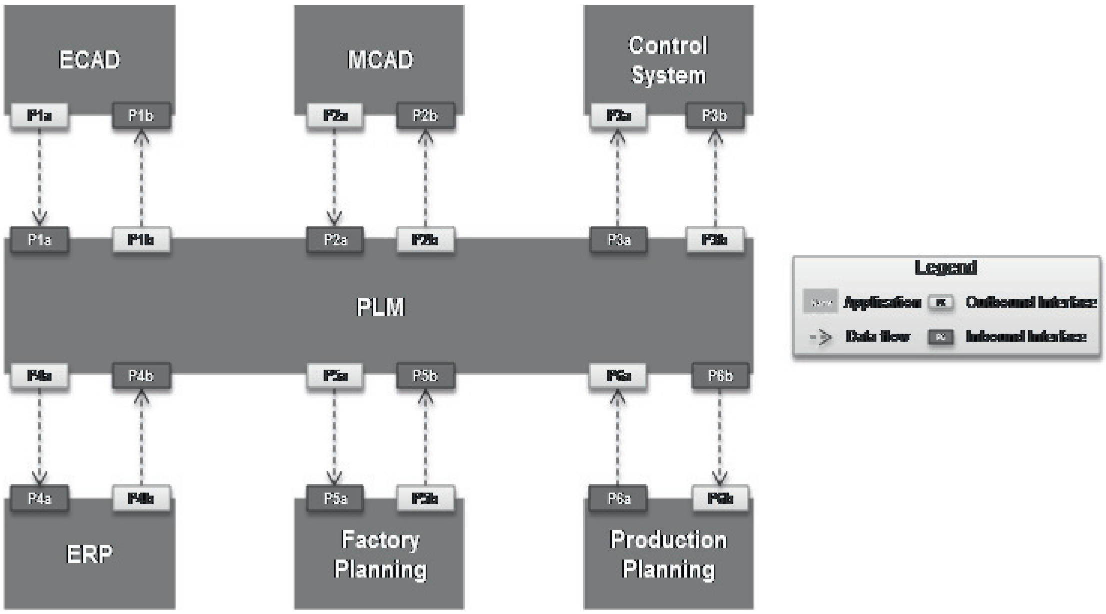

Fig.2. Integrated sample target system landscape within the *Digital Factory* domain.

We developed a reference model in order to improve complex system landscapes like the one described above towards better data integration. It starts with a *Rough Analysis* phase of the current environment. This step can further be split into the three sub-steps *Process Analysis*, *Use-Case Analysis* and *Organization Analysis*. Following the *Rough Analysis* the *Detailed Analysis* step is performed. It consists of the four sub-steps *Input/Output Analysis*, *System Analysis*, *Data Source Identification* and *Data Object Identification*. Finally a *Target Definition* step is performed, which can be split into the three sub-steps *Exchange Format Definition*, *Interface Definition* and *Interface Optimization* (Fig.3.).

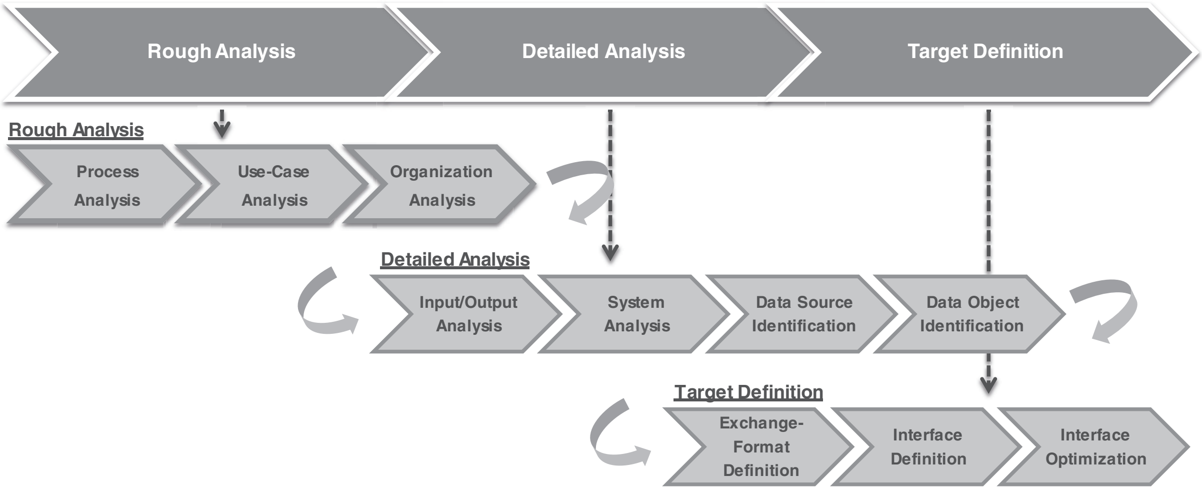

Fig.3. Data integration framework for the *Digital Factory*.

Rough Analysis

The goal of the *Rough Analysis* is to get an overview of the current as-is situation in the company from a process point of view. This step serves as the basis for more detailed analyses at a later point of time. The first task is to perform a *Process Analysis* which identifies those processes in the company which are relevant for the project. The output is on the one hand a survey of the relevant business processes and on the other hand an estimate of the project's dimensions. Following the *Process Analysis,* a more detailed *Use-Case Analysis* is performed in which the previously identified business processes are broken down step by step with the goal of identifying all relevant use-cases in the company. The last step of the *Rough Analysis* is to conduct an *Organization Analysis* where all available roles within the company are identified and related to the processes and use-cases they are involved in.

Detailed Analysis

Following the *Rough Analysis* process a *Detailed Analysis* of the processes will be performed to get a more detailed and information technology based view of the company. The process starts with an *Input/Output Analysis* step to identify the functional input and output for each identified use-case, and all of the factors influencing those use-cases. After this analysis all inputs needed by and all outputs generated by each use-case as well as all influencing factors are identified. At this point an even more detailed *System Analysis* can be performed to identify all of the software systems which are used within the use-cases, as well as the events triggering the respective use-cases. If two applications are used within one use-case, the use-case needs to be broken down further so that only one single application is supporting one use-case. The goal of the analysis is to get to know all applications used in the company, relate them to the business processes in which they are used and identify all process triggers. With this information a process flow based *Data Source Identification* can be performed to pinpoint all data sources which provide the input required by each of the use-cases. The objective is to find out which applications provide input to the use-cases and which subsequent use-cases continue processing the generated outputs. Finally a *Data Object Identification* step is performed. It defines the required data objects for each data source and the format of the output objects (e.g. data format, attributes, values etc.). At the end of the *Detailed Analysis* all existing data objects are identified, related to a use-case and it is known from which application they come from, and in which subsequent application they are further used.

Target Definition

The last process step to be performed is the *Target Definition*. The goal is to define the new integrated system landscape and it starts with the *Exchange Format Definition* phase. Here a standardized interface architecture is defined which will be used for all future cross-application interfaces. From an architectural point of view it needs to be clear if the interfaces are supposed to be active (e.g. web services) or passive (e.g. file exchange). Further a neutral data exchange format (e.g. *AutomationML*) needs to be defined which will be used as a standard for all future interfaces to be realized. The next step is the actual *Interface Definition* where all interfaces will be routed using a central data management system. This means that all applications' outbound data flows will be converted into inbound interfaces to the central data management system. The goal of this step is to define an integrated system landscape where each application solely has one communication partner to exchange data with – the central data management system. Finally an *Interface Optimization* step needs to be performed. It will merge all inbound and outbound data flows triggered by the same event into one single interface unit thus achieving a minimization of the number of interfaces to be realized.

4. Evaluation & Conclusion

The aim of this article was to introduce a data integration framework for the *Digital Factory*. We have shown the problems of the current as-is landscape within the *Digital Factory* domain and defined an improved and integrated target landscape. Subsequently, we introduced a framework that can be used to reach such an integrated landscape by improving the current inefficient landscapes. A mandatory basic condition for the framework to be applied successfully is that in the company a software system with a customizable data format is available, and that this system will be defined as the central data integration platform for the *Digital Factory*.

This framework is currently still in its definition phase and future research has to prove that it can be implemented in practice and achieve the intended goals. For evaluation purposes, prototypes and case studies in cooperation with companies using the *Digital Factory* are recommended. According to [16] the main characteristics of an optimized application landscape are a high degree of reuse (Reuse), a low degree of complexity (Complexity), the possibility to integrate new application with a minimal effort (Effort). Based on this the following table shows some evaluation metrics which could be used in order to measure and compare the success of such prototypes or case studies (Table 1).

Table 1.Evaluation metrics.

Criteria	Affected characteristics according to [16]	Measurement	Description
Application Reduction Rate	• Reuse • Complexity	$1-\frac{No.ofapplicationsafter}{No.ofapplicationsbefore}$	An indicator to show, how many of the existing applications could be cut. Higher values imply better results.
Interface Reduction Rate	• Complexity • Effort	$1-\frac{No.ofinterfacesafter}{No.ofinterfacesbefore}$	An indicator to show, how many of the existing interfaces have been removed. Higher values imply better results.
Data Redundancy Reduction Rate	• Reuse • Complexity	$1-\frac{No.ofredundantdatafieldsafter}{No.ofredundantdatafieldsbefore}$	An indicator to show, how many of the redundant data fields have been removed. Higher values imply better results.
Manual Interface Reduction Rate	• Complexity • Effort	$1-\frac{No.ofmanualinterfacesafter}{No.ofmanualinterfacesbefore}$	An indicator to show, how many of the interfaces which require manual actions have been removed. Higher values imply better results.

In order to extend the research described in this article, a project has been started which will be used to evaluate and improve the methodology described above. This real-life project starts from an existing, heterogeneous system landscape currently used in the context of the *Digital Factory* domain. We will try to optimize this landscape based on our data integration framework and evaluate the process. Based on the project's results we will further enhance the framework in order to improve the research conducted within this area.

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References

[1] L. Aldinger, T. Rönnecke, V. Hummel, E. Westkämper, Advanced Industrial Engineering, Ind. Manag. 22 (2006) 59–62.
[2] Y. Bin, X. Wei, W. Zu-wen, STEP-Based Research and Realization on CAD Data Transformation for Virtual Assembly, 2009 WRI World Congr. Comput. Sci. Inf. Eng. (2009) 707–710.
[3] U. Bracht, T. Masurat, The Digital Factory between vision and reality, Comput. Ind. 56 (2005) 325–333.
[4] D. Chen, T. Kjellberg, A. Euler, eds., Software Tools for the Digital Factory–An Evaluation and Discussion, in: Proc. 6th CIRP-Sponsored Int. Conf. Digit. Enterp. Technol., Springer, 2010.
[5] C.-J. Chung, H.-M. Wee, Short life-cycle deteriorating product remanufacturing in a green supply chain inventory control system, Int. J. Prod. Econ. 129 (2011) 195–203
[6] R. Drath, A. Luder, J. Peschke, L. Hundt, AutomationML - the glue for seamless automation engineering, in: 2008 IEEE Int. Conf. Emerg. Technol. Fact. Autom., IEEE, 2008: pp. 616–623.
[7] S. Faltinski, O. Niggemann, N. Moriz, a. Mankowski, AutomationML: From data exchange to system planning and simulation, 2012 IEEE Int. Conf. Ind. Technol. (2012) 378–383
[8] M. Gregor, S. Medvecky, J. Matuszek, A. Stefanik, Digital Factory, J. Autom. Mob. Robot. Intell. Syst. 3 (2009) 123–132.
[9] F. Himmler, M. Amberg, A Reference Process Based Software Market Analysis for the Digital Factory, in: Proc. IADIS Int. Conf. - Collab. Technol. 2013, 2013
[10] F. Himmler, M. Amberg, Die Digitale Fabrik – eine Literaturanalyse, in: Proc. 11th Int. Conf. Wirtschaftsinformatik, 2013: pp. 165–179.
[11] C. Lee, C. Leem, PDM and ERP integration methodology using digital manufacturing to support global manufacturing, J. Adv. Manuf. (2011) 399–409
[12] F. Maier, M. Stumptner, Enhancements and Ontological Use of ISO-10303 (STEP) to Support the Exchange of Parameterised Product Data Models, Seventh Int. Conf. Intell. Syst. Des. Appl. (ISDA 2007). 10303 (2007) 433–440.
[13] C. Matysczok, D. Meyer, Erfolgsfaktoren bei der strategischen Einführung der Digitalen Fabrik, Zeitschrift Für Wirtschaftlichen Fabrikbetr. 104 (2009) 27–31.
[14] D. Petzelt, J. Schallow, J. Deuse, Data integration in Digital Manufacturing based on application Protocols, in: D. Petzelt, J. Schallow, J. Deuse (Eds.), Comput. Sci. Inf. Technol. (ICCSIT), 2010 3rd IEEE Int. Conf., IEEE, 2010.
[15] A. Schwinn, J. Schelp, Design patterns for data integration, J. Enterp. Inf. Manag. 18 (2005) 471–482.
[16] A. Schwinn, R. Winter, Entwicklung von Zielen und Messgrößen zur Steuerung der Applikationsintegration, in: O. Ferstl, E. Sinz, S. Eckert, T. Isselhorst (Eds.), Wirtschaftsinformatik 2005, Physica-Verlag HD, 2005: pp. 587–606.
[17] X. Yang, J. Dong, Z. Be, The Role and Application of STEP in CAD/CAPP/CAM Integration, (1983)