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FUNCTIONAL MODULES SPECIFIC FOR VIRTUAL MANUFACTURING

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Abstract

Manufacturing stands at the basis of European economy and welfare. The uttermost challenge of manufacturing processes facing global competitors is to improve the quality, reduce the delivery time and decrease the cost. Thus, the need for investing in research and development in the domain of manufacturing became mandatory for the European industry and community. The newest trend for optimizing the manufacturing processes is to introduce virtual manufacturing systems for simulating these processes. Simulations are able to cover all production chains and they facilitate detecting eventual problems at early stages, saving a lot of time, effort and costs compared to real industrial production systems. The areas of high-interest in the research topic of virtual manufacturing and digital factories are closely related to the planning phases of a digital factory. The life cycle of a factory follows a series of stages and phases from the initial concept of the factory to the ecological dismantling. To deliver the required products to the customer and in the same time to face the competitors, several planning functionalities have to be performed for the factory to be ramped-up, monitored and maintained. In order to cover one or more of the factory planning phases, we are designing and developing several functional modules, this way providing exploitable results for some existing industrial enterprises. We established the dissemination, exploitation and validation strategies from the beginning of the planning process of the modules, based on international standards and on advanced modelling/verification techniques. The functional modules are integrated with other existing virtual fabrication systems having well-established data feeding and data extraction mechanisms. The modules address methodologies and tools for agile factory layout configuration and optimization, as well as functionalities for the rapid design and development of reliable automation and control systems. The developed functional modules, thus, are some tools for cost-effective and rapid creation, management and use of complex knowledge-based factories.

Key words: virtual manufacturing, functional modules, PDM, PLM, digital factory, optimization

1. INTRODUCTION

In order to quickly adapt to the continuously changing market demands, technology options and regulations, modern factories have to be modular, scalable, flexible, open, agile and knowledge-based. (Mahdjoub et al, 2010). The new direction in manufacturing is oriented towards the optimization and value creation of products, processes and technologies over their entire life. By approaching all these entities according to the lifecycle paradigm and by implementing in a factory a lifecycle management capability, considerable benefits as faster time to market, lower costs, reduction of rework and rejection dates and more component and technology reuse are achieved. This represents for a factory a tridimensional life cycle space of products; their manufacturing processes and the corresponding used technologies (Moreau et al, 2004; Fischer et al., 2004; Nieminen et al., 2004).

Virtual manufacturing uses a wide range of engineering and planning tools and applications to integrate efficient and effective new information and communication technologies into manufacturing

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processes. It employs the distributed data management, tools for process engineering, tools for presentation and graphic interfaces, participative, collaborative and networked engineering, multi-modal interfaces. Moreover, it has as main output the representation of the factory as it is today. Starting with this digital representation of the factory and employing the virtual manufacturing technologies, simulation tools and specific applications and systems (PDM and PLM systems), the factory and its manufacturing processes are represented in their dynamics. This is the reflection of the "actual" state on the future, the so-called "virtual factory" (Westkämper, 2003).

In order to effectively address all phases of a factory lifecycle, there is a need for support tools, which could be software tools that have been developed or acquired in the recent years. The major PLM system providers offer such support tools for some of the factory lifecycle phases, as factory planning, design and deployment phases. These software tools are not always affordable for the small and medium enterprises. So these enterprises are facing a critical trade-off in their factory planning phases: on the one hand there is the need for more and more complex production systems requiring extensive upstream production planning at the highest resolution and on the other hand, the time frame for the planning process is decreasing and existing tools are complex and expensive.

2. FUNCTIONAL MODULES SPECIFIC TO VIRTUAL MANUFACTURING

When talking about functional modules specific for virtual manufacturing, we can think of the above mentioned supporting tools used in virtual manufacturing processes. These are actually software components which perform some very specific, well-defined set of functionalities used in the virtual manufacturing processes of industrial enterprises. The functional modules are intended to be exploited by more than one industrial company using different virtual manufacturing systems.

The challenge in developing such modules lays in creating their architecture and design such that to provide the desired functionality of the module, but in the same time not to have data structures and fields too specific for a certain application. The data model has to be generic enough for integration in a wider range of applications. On the other hand, most of the functional modules providing certain functionality probably need to be customized until a certain level for each application in turn. If a module is too generic, it might not be sufficient, and if it is too specific than it would probably not be exploited by a wide enough range of users.

The functional modules are characterized by many heterogeneous behaviours and needs. Some of them can be existing commercial applications conveniently equipped with adaptation modules in order to interface with the core of the main applications, while some others can deal with the implementation of particular library functionalities. Realistically, it can be foreseen that most of the modules will configure somewhere in the middle of these two extremes like hybrid solutions.

Fig. 1. *Examples of functional modules along factory life cycle*

There are some module types that are needed for most of the virtual fabrication systems, such as security modules, configuration modules, audit modules and data versioning modules. Other module types differ from system to system, depending on what products are manufactured, what processes are used, what functionalities are needed for costs or performance optimization, for process simulation, and so on. Some examples of functional modules along all phases of the factory life cycle can be seen in figure 1. As their names suggest, they are performing tasks very much related to the respective phases. Although it is desired, in reality it does not necessary happen that all are connected to the same virtual manufacturing core system.

The functional modules have to be able to communicate with the core of the main system through well-defined software interfaces and using predefined data models. This allows extending the base application in a flexible way so that modules can be added or removed to and

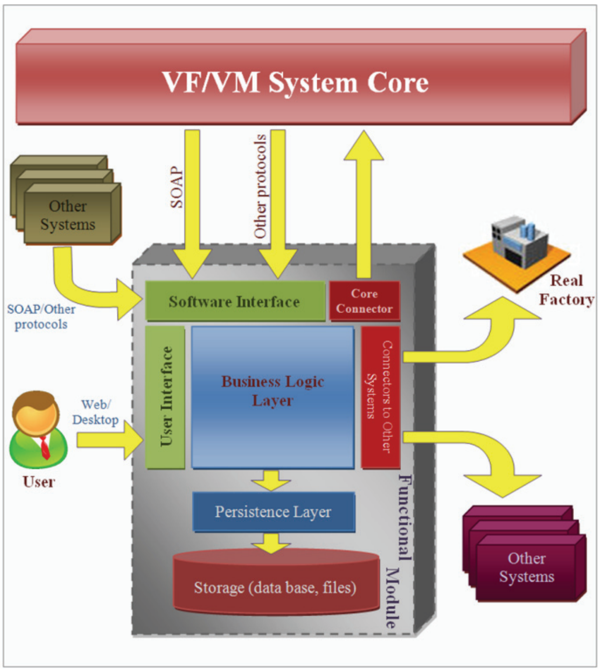

***Fig. 2.** A typical functional module structure.*

from the system without affecting the core functionality. The functional modules design foundations must cope with the basic principle that any module respecting the defined communication interfaces and the common data models can be integrated and seamlessly operate. The basic software design pattern that is followed in general for functional modules is the plugin interface pattern. In figure 2 the typical architecture of a functional module is presented. Beside the standard software interface which enables the core system or other modules to access the functionalities provided by the module in focus, depending on its purposes, a functional module may also provide a graphical user interface. This can be either a stand-alone user interface in which case it needs to be locally installed on user's computer, or it can be a web interface and in this case it is deployed on a remote web server.

The core part of the functional module resides in its business logic layer, which is the most important component of the module. All data processing operations, logic conditions, algorithms, data transformations and data validations are implemented in this part. The interfaces are in fact just an external/formal way to access the functionalities provided by the business layer. Based on the internal flows, the module might need to access/deliver data from/to other parties like:

- the core system itself,
- the real factory devices,
- other software systems.

This is realized through the so called connectors. In case there is data that needs to be stored locally, "inside" the module, then it is enriched with a persistence layer and a storage system that can be a database, a file system, etc.

When developing functional modules, the aim is not to reinvent the wheel. For this reason a way of integrating existing applications must be provided. This job is realized usually through the implementation of adapter modules able to import from - and export to - existing applications the data of the main application. The adapters will be in fact wrappers over already existing implementations which do not respect the required interface.

Since they are designed to be integrated in complex and distributed software suites, all functional modules have to also fulfil different non-functional requirements related to:

- performance,
- data integrity,
- data security,
- quality,
- usability,
- error handling,
- portability.

When creating a functional module, all steps from a regular software development process should be followed, even if the tendency is to skip many of them, since the module is usually integrated as part of a bigger virtual manufacturing system. So these steps should be:

- clarify and analyse the requirements,
- define detailed specifications,
- define validation scenarios,
- define the parameters for the non-functional requirements,
- identify the integration points with other modules/systems (input and output interfaces),
- design the module,
- perform the software implementation using appropriate technologies and programming languages,
- verify and validate the module,
- deploy the module into production,
- maintain the module (e.g. in case other systems to which this module is connected are changed, then also this module might have to be changed).

3. FUNCTIONAL MODULES IN VIRTUAL FACTORY FRAMEWORK (VFF)

One of the large-scale European projects dealing with the topic of virtual manufacturing is the *Holistic, extensible, scalable and standard Virtual Factory Framework* in which more than 30 organizations are involved. The approach presented in the Virtual Factory Framework supports the manufacturing enterprises to face the nowadays challenges. The project uttermost objective is to foster and strengthen the primacy of Future European Manufacturing by defining the next generation Virtual Factory Framework. This project will support the capability to simulate dynamic complex behaviour over the whole life cycle of Factory, approached as a complex long living Product. Thus, the project will research and implement the underlying models and ideas at the foundation of a new conceptual framework designed to implement the next generation Virtual Factory, also meant to lay the basis for future applications in this research area. Out of these domains of interest, several functional modules can be planned to cover one or more of the factory planning phases and provide this way exploitable results for the industrial partners. These functional modules are designed in close collaboration with the interested industrial partners who are aimed to be the final users of the modules. This implies planning the functionality and the objective of the modules in such a way that these would be part of one or more factory planning phases presented above.

The core part of VFF is the Virtual Factory Manager component. It is responsible for orchestrating the abstract objects describing each element composing the manufacturing environment and their relations in order to perform a specific required activity, e.g. workplace simulation. The VF manager guarantees data consistency and availability to all decoupled functional modules while being also in a tight integration with the knowledge repository engine. The functional modules will implement the various tools and services for the factory design, reconfiguration, management and so on. They operate independently on the same Common Space of Factory Abstract Object. The representation of this common space is based on the Factory Data Model. The modules are respecting the interfaces defined by the VF Manager and based on the Factory Data Model they can be easily integrated. The specific modules will be deployed addressing new methodologies and innovative tools for agile factory layout configuration and optimization, as well as functionalities for the rapid design and development of reliable automation and control systems, based on the exploitation of international standards and on advanced modelling/verification techniques, thus enabling the conception and re-configuration of agile automation systems.

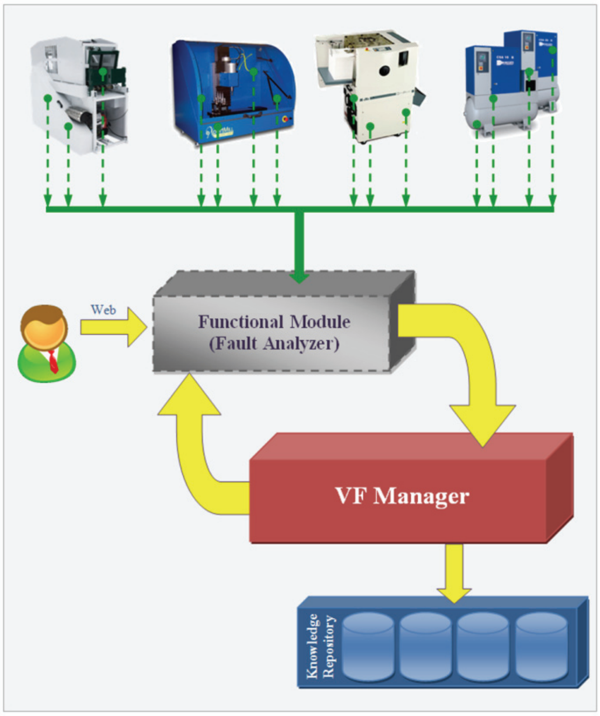

Fig. 3. Fault Analyzer – functional module schema.

The research team of the Technical University from Cluj-Napoca is involved in two of the main VFF project components: the Functional Modules and the integration with Real Factory – Factory Image. One functional module, which is connected to both topics, is a so called Fault Analyzer module. It is going to solve a very practical problem the industrial partners currently have: the long time needed for collecting, centralizing and summarizing the failure data coming from the sensors of the physical factory machines. This is done at the moment using Excel files. As shown in figure 3, this module will be a central system for collecting the data from the real factory, and out of the collected data to extract statistical information (reports, charts, etc.) in an automatic way. This way it can be detected for example which are the most important failures, their reasons, duration, etc. It can be also detected how many times a specific type of component is broken and use this information later on to calculate how many components are needed to provide an efficient functioning. All these results are very useful for improving the proposal, factory planning and factory ramp-up phases of the next projects, saving a lot of time and costs. The entire data that is collected will be saved in the VFF Knowledge Repository through the VF Manager, instead of a local module storage, so that it may be used also by other modules/components of VFF. The module will provide a web interface and this way its features can be provided also to the end users not only to software systems.

4. CONCLUSIONS

The VFF research project will promote major time and cost savings while increasing performance in the design, management, evaluation and reconfiguration of new or existing facilities, supporting the capability to simulate dynamic complex behaviour over the whole life cycle of a manufacturing process. Expected results in VFF project are collaborative customer-driven virtual factory tools (based on the new paradigm of seeing the factory as a product) for cost-effective and rapid creation, management and use of complex knowledge-based factories. These tools for the collaborative design will foster temporary partnerships and new business and management processes in virtual company networks. The broad range of possible functional modules ensures the holistic view on the entire production system including environment and social aspects.

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FUNKCJONALNE MODUŁY DEDYKOWANE DLA WIRTUALNYCH TECHNOLOGII WYTWARZANIA

Streszczenie

Procesy produkcyjne są podstawą ekonomii i dobrobytu w Europie. Poprawa jakości wyrobów, skrócenie czasu dostaw i obniżenie kosztów produkcji są najważniejszymi wyzwaniami jakim procesy wytwarzania muszą sprostać w dobie globalnej konkurencji. Stąd wynika konieczność finansowania badań w obszarze wytwarzania, narzucona na przemysł w przez instytucje europejskie. Wprowadzenie systemów wirtualnej technologii procesów wytwarzania i symulacji tych procesów to najnowsze trendy w optymalizacji. Symulacje mogą obecnie obejmować całe cykle wytwarzania i umożliwiać wykrywanie ewentualnych problemów przed rozpoczęciem produkcji, co pozwala na oszczędność czasu i kosztów w porównaniu do stosowanych tradycyjnych metod wdrażania technologii. Obszary największego zainteresowania badaczy zajmujących się wirtualizacją technologii są ściśle związane z fazą planowania wirtualnej fabryki. W swoim cyklu życia fabryka przechodzi przez szereg etapów i faz od początkowej koncepcji aż do końcowego poprawnego ekologicznie demontażu. Aby dostarczyć wymagany produkt klientom i sprostać konkurencji, system musi mieć szereg funkcjonalności związanych z planowaniem, monitorowaniem i utrzymaniem ruchu. W niniejszej pracy zaprojektowano i opracowano szereg funkcjonalnych modułów, które objęły jedną lub więcej faz planowania fabryki i dostarczyły praktycznych wyników dla wybranych istniejących zakładów przemysłowych. Ustalone zostały strategie rozpowszechniania, eksploatacji i weryfikacji danych od początku procesu planowania poszczególnych modułów. Strategie opierają się na międzynarodowych standardach oraz na zaawansowanych technikach modelowania i weryfikacji. Moduły funkcjonalne zintegrowano z istniejącymi wirtualnymi systemami wytwarzania zapewniając efektywne układy wymiany danych. Te moduły uwzględniają metodyki i narzędzia dla sprawnego zaprojektowania optymalnej konfiguracji fabryki oraz dla zapewnienia funkcjonalności szybkiego projektowania. Pozwalają one też na stworzenie skutecznych systemów sterowania i automatyzacji. Opracowane moduły funkcjonalne są narzędziem dla oszczędnego i szybkiego tworzenia, zarządzania i wykorzystania kompleksowych fabryk opartych na wiedzy.

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