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CONFIGURATION OF FACTORIES AND TECHNICAL PROCESSES: WHICH ROLE PLAYS KNOWLEDGE MODELLING?

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КОНФІГУРАЦІЯ ПІДПРИЄМСТВА Й ПРОМИСЛОВИХ ПРОЦЕСІВ: ЯКУ РОЛЬ ГРАЄ МОДЕЛЮВАННЯ БАНКУ ЗНАНЬ?

Стаття представляє наші перші дослідницькі кроки, що переслідують ціль розвитку методології для побудови конфігурації, що ґрунтується на банку знань, підприємства й промислових процесів. Звернено увагу на необхідність впровадження вперше розглянутого комплексного завдання конфігурації баз знань як високоефективної технології. Аналіз необхідних умов проілюстрований мотиваційним сценарієм, що походить з аналізу реальної інформації, взаємозв'язків технологій і їхньої пристосовності для перекомпонування виробничих потужностей. Статтю завершує вибір підходящих до застосування технологій і дорожня карта майбутньої активності.
Ключові слова: конфігурація, планування виробництв і процесів, модель бази знань.

Статья представляет наши первые исследовательские шаги, преследующие цель развития методологии для построения основывающейся на банке знаний конфигурации предприятия и промышленных процессов. Обращено внимание на необходимость внедрения впервые рассматриваемой комплексной задачи конфигурации баз знаний как высокоэффективной технологии. Анализ необходимых условий проиллюстрирован мотивационным сценарием, вытекающим из анализа реальной информации, взаимосвязей технологий и их приспособляемости для перекомпоновки производственных мощностей. Статью завершает выбор подходящих к применению технологий и дорожная карта будущей активности.
Ключевые слова: конфигурация, планирование производств и процессов, модель базы знаний.

The paper presents our first research steps aiming at the development of a methodology for knowledge-based configuration of factories and technical processes. The complex task of configuration is firstly introduced and the need for embedding knowledge as an enabling technology is pointed out. The requirements analysis illustrated by a motivation scenario is followed by the analysis of state-of-the-art information and communication technologies and their particular applicability for the configuration of production facilities. The paper concludes with the selection of suitable enabling technologies and the roadmap of future activities.
Keywords: Configuration, Factory and process planning, Knowledge modelling.

1 GROWING EFFORT FOR FACTORY AND PROCESS PLANNING

Manufacturers have to handle shorter product life cycles and growing ranges of variants, to stay sustainable in an enormous national and more and more international competition. That induces an increasing need for adaption of existing factories and development of new processes or production facilities.

Every single new or redesign of a production requires its own planning project. That leads to a constantly growing frequency of factory and process planning projects. In addition to this challenging perspective, the complexity in manufacturing and in the corresponding planning projects increases [1].

These two points, the higher frequency and the increasing complexity of planning projects, lead to exponential increasing effort, which gets more and more difficult to manage for today's manufacturers. The research topic presented in this paper aims at the reduction of the effort explained above. The approach is to support the planning of whole factories and technical processes with configuration.

In this context configuration means to find a solution by combining predefined components, which satisfies costumer needs without violating any constraints [2]. Configuration models describe the structure and the technical and economic constraints. Customer requirements can be seen as additional constraints. Thus, the customer requirements represent the input and the solution, configured with help of the configuration model, the output of a configuration process [3]. A configuration engine undertakes the task of computing valid solutions with help of the configuration model. This configuration engine is not focus of the early stage of research introduced here.

According to the industrial paradigm 'Factory as a Product', factories are complex socio-technical products, which contribute to value creation by efficient transformation of resources into high-adding value products [4]. The next step is to adapt technologies of product configuration for the overall goal of decreasing the effort for factory and process planning. The knowledge about methods and models which are used to configure highly complex products supports the development of a comparable model and methodology for factory and process configuration.

This paper introduces our first research steps in developing a configuration approach for planning factories and technical processes.

Some terms used in this paper have to be clarified in advance. The model to represent configuration knowledge is called Factory and Process Configuration Model (FaCoM). This model consists of objects and their relations. The configuration objects can be configuration steps or configuration items. Configuration steps represent the components of the configuration process. This process provides the overall structure for the model introduced here. And for the decisions, made in the respective configuration steps, the term configuration item is used in this paper. These configuration items are composed of attributes and ports. Attributes specify descriptive features (definition, classification, technical and functional characteristics etc.) and ports represent interfaces and relations to other objects [5].

After highlighting the great potential and the requirements for such a model, an overview over the state of the art in the fields of factory and process configuration and the corresponding information and communication technologies is given. Afterwards the approach is introduced and a roadmap concludes the paper regarding future activities to create a foundation for the support of planning processes by flexible, sustainable and time and cost saving configuration of factories and technical processes.

2 POTENTIALS IN CONFIGURATION OF FACTORIES AND TECHNICAL PROCESSES

This chapter concretizes the motivation and great potential behind the approach of configuring factories and technical processes. While going through a planning project, a huge amount of explicit and tacit knowledge is generated. A large number of decisions are made and every single decision has its own reasons. Sometimes these reasons are obvious (e.g. use of a turning machine when the product is a usual shaft), sometimes not (e.g. the factory planner chooses the bigger buffer than the calculations recommend, because he 'knows', that there can occur unforeseen problems).

Probably an employee, planning factories for years, gets the feeling of always doing the same to some extend in every planning project. He or she always creates knowledge to come to substantiated decisions. Normally it is hard to find two decisions in two different planning projects that are completely the same. But he has this feeling. But why is it not possible for the planner to use a solution from planning phases of former projects? Because he does not know all the influences, constraints and interdependencies, that made the decision (so-called configuration item) to an optimal solution. He does not know whether the already generated solution is really suitable for the new problem. He does not know how the solution affects other configuration objects. The planner is not able to foresee the impact of choosing the solution on the aspired objectives of the actual planning project.

But what if a model 'knows' all these interdependencies and influences? Such a model is able to decrease the complexity of a planning project by structuring it [6]. And through embedding knowledge about possible influence of and interdependencies between configuration items and configuration steps, valid solutions can be configured. For the calculation of valid solutions, this model needs to 'know' all relations and constraints. Thus, knowledge embedded in a reference model enables a well-found statement about the impact an already generated solution would have on an actual planning project and the corresponding objectives. The knowledge embedded in the model provides information about what influence a special configuration item has on another (e.g. when choosing this solution, you have to or you can't choose that).

The configuration model presents the relations between configuration objects and the embedded knowledge enables a characterization and classification of these relations. The corresponding term for this knowledge-rich reference model is Factory and Process Configuration Model (FaCoM) like mentioned before. With this model the factory planner can estimate the impact of a single configuration item on the whole project and is in the position to use a solution of former projects. When knowing this, the employee needs much less experience in factory planning because the planner is able to use solutions of former projects and the configuration model shows the impact. In this paper the input knowledge for using FaCoM is separated into two types: Project-specific (e.g. manually inserted knowledge for actual configuration problem) and historical (e.g. former planning activities) configuration knowledge.

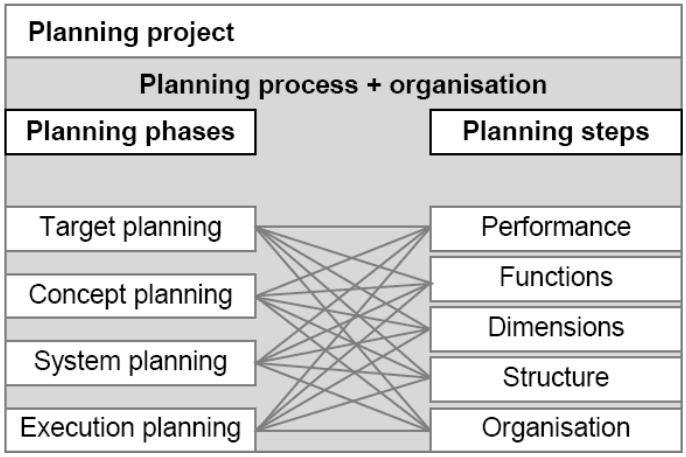

Figure 1 – Hierarchy of planning processes (adapted from [7]).

3 STATE OF THE ART ON ITS WAY TO FACTORY AND PROCESS CONFIGURATION

The first part of the following analysis regarding the state of the art in field of factory and process configuration is the factory planning. Especially modern concepts and models for factory and process planning which are probably suitable to provide a structure for FaCoM are analysed. The second part is represented by an analysis of state-of-the-art methods and technologies for product configuration with a special interest to the used information and communication technologies (ICT). First approaches of configuring factories and processes are introduced and examined as the third and last foundation part of this state of the art analysis.

3.1 Model-based factory planning

This section addresses the state-of-the-art model-based factory planning. That is of relevance due to the ambition of using, adapting and extending already existing models for factory planning to make them feasible as a structure for FaCoM.

Figure 1 shows, how the following terms are used in this paper. The planning process is the structure of a planning project. This process arranges planning phases, which consist of single planning steps.

Systematisation and structuring of factory planning projects has a long tradition [8]. Process oriented methodologies [9] are more and more switching to object oriented approaches. This changeover is to provide planning processes with flexibility. Planning projects cannot be standardized to be really supported by one of these rigid phase oriented processes. Model driven factory planning represents the next step for structuring object oriented planning projects [6]. The objects are mostly characterized as planning phases or activities. Some model-based planning processes can be identified, describing the planning phases in different granularity [10]. One of the most important representatives for model based factory planning is the 'Reference Model for Factory Engineering and Design' (Figure 2). This model claims to be on its way to a holistic reference for factory and process planning. These models provide detailed andsubstantiated structures for the planning of processes and factories, which are analysed to be used and/or adapted for FaCoM.

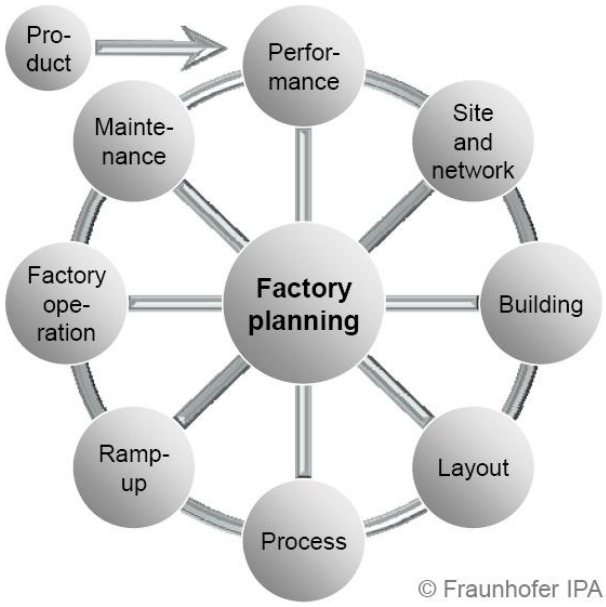

Figure 2 – 'Reference Model for Factory Engineering and Design' (adapted from [11]).

3.2 Configuration concepts with corresponding ICT

Due to the fact, that the research topic introduced in this paper is in an early stage, this section deals with concepts and models and the corresponding ICT used in the field of configuration. It is not about an analysis of state-of-the-art configurators. Customer interfaces for knowledge acquisition, ICT for problem-solving or something like this is not the focus of this contribution.

To arrange configuration methods, they are classified according to the structuring of configuration knowledge. The main concepts are introduced here [5]:

• Rule-based systems are also known as expert systems using rules for the representation and computing of configuration knowledge. The main problem with this kind of configuration operation is the maintenance. This is caused by the lack of an organization of defined rules [12].

• Model-based systems provide this organization by a system model, which enables a modularization by implementing decomposable objects with their interdependencies. It supports the separation between what is known and how the knowledge is used. The Unified Modeling Language (UML) [13] provides an easy to use notation for modelling complex configuration systems [14]. Model-based configuration can be further classified [15].

○ Logic-based reasoning is based on declarative description logic, which is to represent knowledge. It is based on objects, which are interrelated and subsumed to classes.

○ Resource-based approaches organize and characterize their objects as resources they supply, use and consume [16]. A very interesting issue with resource-based reasoning is the separation of system, catalogue and heuristic knowledge. This provides a clear separation of what an object is, its characteristics and the knowledge how this can be used. This approach is useful for finding a solution covering desired functionalities. But problems can occur, when it is forced to deal with structural and specific placement requirements.

○ Constraint-based systematization offers another representation of the relations by ports of configuration objects, which allow, forbid and/or characterize connections to other objects [17].

• Case-/context-based reasoning addresses a configuration problem solving by former generated solutions. For instance, this reasoning is used in connection with fuzzy logic to identify historical cases which can be used or adapted [18]. This approach suffers from the difficulty of acquiring knowledge in form of enclosed cases and from a lack of support for maintaining knowledge bases for case-based reasoning [19].

• Genetic algorithm-based product configurators focus on one-of-a-kind production. Because of ANDOR trees as the modelling method used here, this reasoning is only suitable for configuration problems, where only a few configuration constraints exist [20].

• Ontology-based representation of configuration knowledge is a very promising approach. Under this topic, semantic web technologies like Web Ontology Language (OWL) [21] and Semantic Web Rule Language (SWRL) [22] are used to model configuration knowledge including the necessary knowledge base and the configuration engine. This approach claims to support a

re-use of configuration knowledge on an unreached level [23]. By connecting data with semantic meta data, the ontology-based approach aims at an automatic readability of knowledge.

3.3 Configuration of Factories and Processes

This section is about existing approaches for supporting factory and process planning activities with configured recommendations or solutions.

According to product configurators serving as a basis for initial investigations in the field of factory and process configuration, an approach from Homag Holzbearbeitungssysteme GmbH (HOMAG) is the first example. As a leading provider of equipment for wood machining, HOMAG is very engaged in configuring its products. As the products of HOMAG can reach to whole production lines, the configuration of these can be used as an example for a first step into the direction of the configuration of factories. But this configuration approach is meant to deal only with a small set of standardized components [24].

In the field of configuring technical processes, the TECHBASE in connection with INNOTECH and RATECH has to be mentioned. TECHBASE serves as an information system for technologies. INNOTECH is to identify innovative technologies and RATECH helps finding the suitable technology by providing evaluations of different technologies. These systems are not meant for the configuration of technical processes, but they support process planning activities with recommendations about usable technologies [25].

These similarities with configuration approaches can provide valuable input for the approach introduced here. This summary of the state of the art regarding the development of a model for the configuration of factories and technical processes represents the basis for the approach introduced in the following section.

4 THE WAY TO THE FACTORY AND PROCESS CONFIGURATION MODEL - FACOM

4.1 Foundations for FaCoM

The pursued approach in the topic of configuring factories and processes is to develop a generic, adaptable and above all knowledge-based model, which serves as a backbone for the development of future configurators. This model will provide all capabilities, which are required to realize a significant reduction of the effort for planning and adapting factories and technical processes by offering automatically configured recommendations.

Due to the fact, that a factory planning project is a very complex topic, it is very challenging to organize such a huge and manifold amount of knowledge to enable a configuration. The high rate at which knowledge changes, requires special attention in maintaining the knowledge base. To face these challenges, the approach introduced here pursues an ontology-based reasoning. Semantic

web technologies enable an organization of highly heterogeneous knowledge. All descriptions, classifications and characterizations of configuration objects are stored in a configuration ontology. This ontology forms the knowledge base. The structure for rganizing the knowledge base is provided by a reference model for factory and process configuration. The combination of the ontology-based reasoning with a model-based structure supports the maintenance of knowledge and thus enables the organization of highly heterogeneous and fast changing knowledge. This knowledge-rich configuration model is shown in Figure 3.

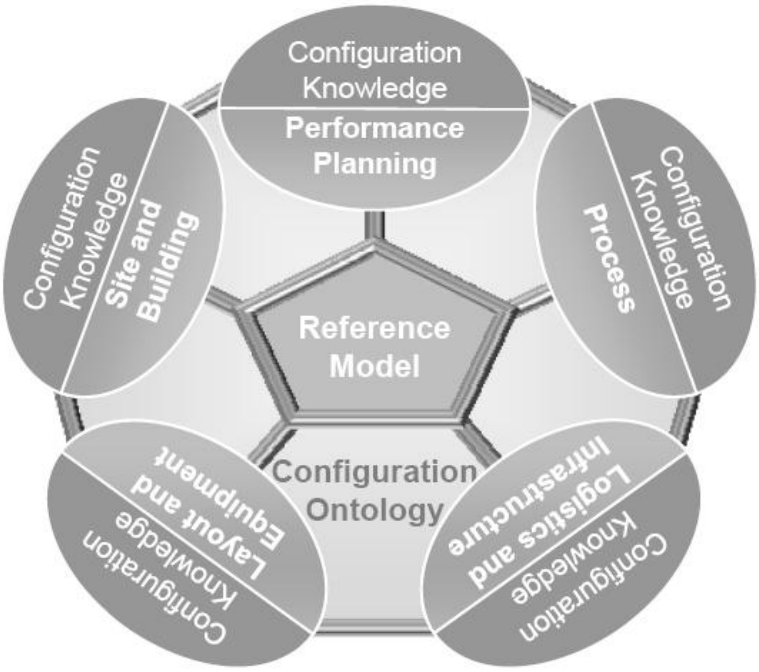

Figure 3 – Factory and Process Configuration Model (FaCoM).

4.2 Roadmap to FaCoM

Due to the configuration of factories and technical processes as a very new and complex research topic, the activities for the next years are of special interest. The next research step will be to concretize the applicability of an ontology-based organization in combination with a model-based structure.

This will be followed by adapting existing reference models for factory planning as a structure for FaCoM. In parallel, an ontology for factory and process configuration knowledge will be developed. Afterwards the knowledge base will be connected with or embedded in the reference model for factory and process configuration. These represent the three foundation pillars for FaCoM:

- Ontology-based knowledge organization.
- Model-based knowledge structuring.
- Connection of both by embedding the knowledge in a reference model.

While pursuing this goal, some challenges have to be faced:

- Classification of configuration knowledge.

• Proper modularization of a generic factory configuration project to define single phases and steps as configuration objects.

• Acquisition of knowledge without an ICT expert and without a significantly increasing effort for the technical expert.

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