1

Knowledge-based Production Planning – A Summary

Benjamin Gernhardt[1], Tobias Vogel[1], and Matthias Hemmje[1]
[1] University of Hagen, Germany

Abstract. The manufacturing of a product takes place in several partial steps and these mostly in different locations to, e.g., save tax or to use the best providers. Therefore, in the era of Industry 4.0 and ***Internet of Things (IoT)***, modern ***Intelligent Production Environments (IPEs)*** set inevitably on a cloud-based repository and architecture to make data and information accessible everywhere as well as development processes and knowledge available worldwide. Semantic approaches for knowledge representation and management as well as knowledge sharing, access, and re-use can support ***Collaborative Adaptive Production Process Planning (CAPP)*** in a flexible, efficient, and effective way. Thus, semantic representations of such CAPP knowledge integrated into a machine readable process formalization is a key enabling factor for sharing such knowledge in cloud-based knowledge repositories supporting CAPP scenarios as required for, e.g., ***Small and Medium Enterprises (SMEs)***. When contributors work together on a product planning, they exchange component and process change information between different planning subsystems, e.g., utilizing a standardized production-feature representation. That can be achieved by applying the already established ***Standard for the Exchange of Product model data (STEP)*** for the computer-interpretable representation and exchange of product manufacturing information. Furthermore, the planning process is supported by so-called ***Function Block (FB)*** based knowledge-representation models, utilized as a high-level process representation template. Web-based and at the same time Cloud-based tool suites which are based on process-oriented semantic knowledge-representation methodologies, such as ***Process-oriented Knowledge-based Innovation Management*** (German: **W**issens-basiertes **P**rozess-orientiertes **I**nnovations **M**anagement, **WPIM**) can satisfy these needs. In this way, WPIM can be applied to support the integration and management of distributed CAPP knowledge, as well as its access and re-use in a machine readable and integrated representation. On the other hand, such machine-readable knowledge can be shared within a cloud-based semantic knowledge repository. To integrate all these functionalities, a new method, called ***Knowledge-based Production Planning (KPP)*** is introduced and its advantages are demonstrated.

Keywords: Function Blocks, DPP, CAPP, Process Planning, Process-oriented Knowledge Management, Knowledge-based Production Planning, WPIM, Semantic Knowledge Representation, Knowledge Repositories, Mediator Architecture, Cloud Manufacturing, STEP

1.1 Introduction, Motivation and Problem Statement

The general concept of developing a knowledge-based and process-oriented CAPP support by using the WPIM method as a basis was proposed in [1]. The WPIM approach offers the possibility of modeling and representing innovation processes in a machine-readable semantic format. Furthermore, WPIM enables annotating the process representation in a semantic way with further knowledge resources. This whole knowledge representation structure can then later be accessed, e.g., by means of semantic queries. However, so far WPIM has only been applied in domains like design and development where it also included ***Product Life Cycle Management (PLM)*** support. This means, it has not yet been practically applied in the domain of CAPP. In parallel to the development of WPIM, Wang et al. have introduced a method for representing web-based ***Distributed Process Planning (DPP)*** activities in [3], [4], and [5]. In the following, we will use slightly adapted excerpts from [3] to introduce the necessary concepts and rationale of the DPP method. The DPP method includes also the concepts of ***Meta Function Blocks (MFBs), Execution Function Blocks (EFBs), and Operation Function Blocks (OFBs)***.

Furthermore, Helgoson et al. explain in [6] that "Today, machining-feature based approaches combined with ***Artificial Intelligence (AI)*** based methods are the popular choices for process planners". Their introduced approach is already based on a DPP modeling-method but does not yet support machine-readability and semantic interoperability of such models as it could be achieved by utilizing representations as available in nowaday's semantic web technologies and as, e.g., supported by WPIM. This means, while the proposed DPP approach is very useful and valid in terms of representing the product and machining features within MFBs, EFBs, and OFBs it does not yet support semantic-web based cross-organizational and cross-domain knowledge sharing like it is needed by DPP. However, this is necessary to make such knowledge more widely available e.g., to be shared in collaborations of SMEs within CAPP activities. Therefore, this DPP knowledge is currently not available in a machine-readable semantic representation at all.

Furthermore, the interoperability of such a representation with technologies of the semantic-web and therefore with other applications and tools, like, e.g., from the area of AI and ***Machine Learning (ML)***, cannot easily be achieved. Moreover, this knowledge can not easily be automatically shared, managed, accessed, exchanged, and re-used within collaborations that take advantage of cloud-based semantic repositories of CAPP-knowledge. However, assuming the existence of such a semantic and process-oriented CAPP-knowledge representation, utilizing it by means of other semantic-web technologies would enable cross-domain and cross-organizational interoperability. Therefore, an integration of cloud-based semantic CAPP knowledge repositories with other, e.g., AI and CAPP-support technologies would need to be achieved by means of integrating them based on the semantic web software development paradigm.

In consequence, this insight requires the application of semantic technologies to knowledge sharing and mediation in CAPP processes. In this way process-oriented semantic representations of CAPP knowledge in which the ***Product Features***

(PFs) and ***Machining Features (MFs)*** are formalized within MFBs, EFBs, and OFBs like domain-specific representations, i.e., domain models of the DPP knowledge domain, could support the CAPP knowledge domain. Based on this insight, in our preceding paper "Supporting Production Planning through Semantic Mediation of Processing Functionality" [31], we have already been describing in detail the design and an implemention architecture necessary to enable DPP knowledge resource representations and their semantic-web integration approach for supporting KPP within a so-called ***Mediator Architecture (MA)*** [14]. Such MAs are typical for distributed implementations of semantic-web repositories and are solving semantic integration challenges as well as integrating several distributed, cross-domain and potentially cross-organizational, i.e., local knowledge sources into a global, potentially cloud-based, semantic repository. Furthermore, we have already explained that this can then be considered a semantic and cloud-based CAPP-knowledge repository which has been implemented in a very (technologically) open and distributed way. From the point of view of WPIM, we have also demonstrated the domain models for MFBs, EFBs, and OFBs can be covered by a semantic integration in this repository with the existing WPIM domain concepts of **WPIM-Master Processes**, -**Process Instances**, -**Tasks** and –**Activities.** Thus, it supports the integration of WPIM- and DPP-based knowledge resource modeling, as well as the semantic representation of cross-domain and cross-organizational DPP knowledge to become available as a knowledge-based support to CAPP activities.

In the remainder of this paper, KPP will be explained in more detail. Referred to our previous paper [31], we will explain briefly and in summary FBs and the related concept of MFBs, EFBs, and OFBs. Furthermore, in the State of the Art the FB-based production planning models and the proposed DPP method will be revisited. We briefly describe the State of the Art w.r.t. Process Ontologies and the WPIM-Ontology as well as the basics of the mediator technology. We will carry out a comparison of the DPP modeling approach of Wang et al. [3] with the expressiveness of the WPIM-Ontology. Finally, the KPP method which combines all the advantages of these technologies to semantically wrap, mediate, and integrate the DPP planning processes and the resources will be explained in Section 3. Finally, discussions, future work, and conclusions are provided in Section 4.

1.2 State of the Art and Analysis

The following State of the Art will briefly summarize all the technologies used and integrated for enabling KPP. The section is based on a slightly adapted excerpt from [3] and on the WPIM-based semantic process-modeling.

1.2.1 Function Blocks

FBs are initially defined in the IEC 61499 standard [7] which explains the usage, development, and implementation of FBs in distributed industrial process-measurement and -control systems in a component-oriented approach [8]. IEC

61499 was developed jointly from the existing concepts of FB diagram in the Programmable Logic Controllers (PLC) language standard IEC 61131-3 [9] and standardization work concerning Fieldbus [9]. An FB is an event-triggered component containing algorithms and an Execution Control Chart (ECC) with inputs and outputs of data and events. A literature review related to the FB related research targeting the areas of machining and assembly is available in [3] [4].

1.2.2 Distributed Process Planning

As outlined in more detail in [3], the three core components of the DPP are namely the planning sub-processes of ***Supervisory Planning (SP), Operation Planning (OP)*** plus a new ***Execution Control Planning (ECP)*** which are explicitly modeled in a conceptual ***ICAM Definition for Function Modeling (IDEF0***, where '***ICAM***' is an acronym for ***Integrated Computer Aided Manufacturing***) process formalization model together with their inter-relationships and dataflow.

Within DPP, ***Meta Function Blocks (MFBs)*** are used to encapsulate machining sequences (of setups and machining features) and only contain generic information about the process planning of a product. Therefore, a MFB is a high-level process template, with, e.g., suggested cutting tool types and tool path patterns for subsequent manufacturing tasks.

Furthermore, ***Execution Function Blocks (EFBs)*** are the FBs that are ready to be downloaded to a specific machine. Basically, an EFB can be created by instantiating a series of MFBs associated with a task. Each manufacturing task corresponds to its own set of EFBs, so that the monitoring functions can be conducted for each task unit.

Finally, ***Operation Function Blocks (OFBs)*** have the same structure as EFBs. However, an OFB specifies and completes an EFB with more detailed, machine-specific data about machining processes and operation sequences. Wang et al. use the two different terms of EFB and OFB in [3].

1.2.3 WPIM

The concept of WPIM was developed to support capturing and usage of knowledge around innovation processes [1] [2] [10]. It assumes that innovation has both a knowledge and process perspective which need to be used in a combined manner. Therefore, activities of a process can be annotated with resources, such as experts and documents [10]. The semantic schema of the WPIM application and the corresponding tool suite is based on the ***Resource Description Framework (RDF)*** [11] and enables semantic-based searching by using the ***SPARQL Protocol And RDF Query Language (SPARQL)***. The ***Web Ontology Language (OWL)*** [12] [13] allows to model concepts in classes and, sub-classes (i.e. in a Taxonomy) as well as in additional well-defined formal relations between these (i.e. in a Grammar). These enabling technologies provide a well-defined formal and therefore machine-readable semantic description of knowledge.

With the concepts of ***Master Processes (MP)***, ***Process Instances*** (***PI),*** as well as **Activities** and ***Tasks*** (see **Figure 1)** the separation of modeling and representing generic and instance specific knowledge is supported. In this way, the process artifact representation toolbox of WPIM allows re-using process steps and their associated knowledge in a seamless way.

WPIM has already been applied to represent PLM data in the field of design and development of technical products. In both domains next to executing processes also planning processes has been modeled and used for representation. Semantics as offered by WPIM have the advantage of being easily exchangeable and machine-readable. This helps, e.g., to plan cross-domain and cross-organizational, i.e., distributed innovation processes. The following **Figure 1** describes the interaction of a MP with its PIs. If such processes need to be represented in WPIM, in a first step the user selects classes in the WPIM ontology repository to register an instance of a process resource. This means, the user e.g., selects the process classification systems to be used as the global set of ontologies. In a second step, the user selects attributes for each selected resource class for populating virtual objects in these classes with content resources.

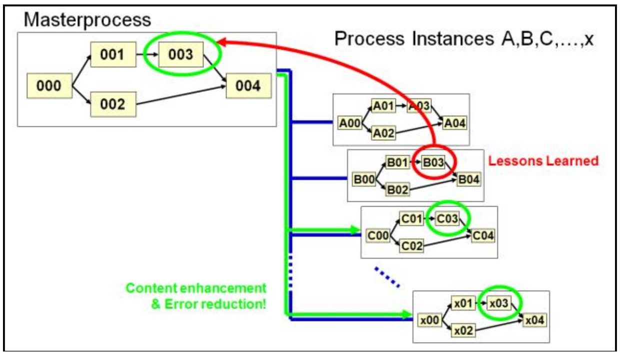

Figure 1. Master Process and Process Instances [2]

This implies, the user has also, e.g., to map the attributes of the resources to specific ontologies. Thus, indicating that an attribute's contents (their range) are mapped to an ontology, such as mapping a resource attribute onto an expert ontology. Finally, the user selects the populating methods or populates the resource instances and their specific content manually. This means, the user maps the attributes of contents to classes in the ontology manually or semi-automatically using word-matching or other provided techniques, e.g., to map "hole" from a product property ontology concept to the "drilled hole" concept in the machining feature ontology.

However, before such mappings can be established, the information and knowledge sources' local data schemas must first be registered. For example, in our implementation we used the two activity-based schemas displayed in **Figure 1** for representing the MP and PI resources.

A MP is a generic high-level description of a process. In WPIM, from a data set point of view, a MP describes a data structure and attributes of a higher level template for a process. The representation approach goes beyond the sole representation of the process structural schema but describes process structures and their attributes by using semantic representations. As WPIM offers such semantic descriptions of MPs, the semantic MP schema exists as a generic and formal description of a process, independent of generated data instances during a certain execution of the process. Resources, which will be involved during execution the process. These resources can, e.g., be experts, documents or, in the case of our CAPP adaptation, can be production machines and their production activities.

When executing a process, data is gathered and has to be managed. WPIM describes this, from the data set point of view, as a PI. The Activity structure that exists in WPIM is used to store all outgoing and incoming data as well as Activity states. Beyond that, WPIM also allows to describe and represent PIs including their Activities in a semantic, machine-readable format. Furthermore, WPIM's PIs are ordered in a chronological way. That means, if a first instance is, e.g., executed, the Lessons Learned during that execution can be stored within the higher level MP and this gathered information can be provided for the following process execution within the next PI (see **Figure 1**).

An **Activity** needs well defined inputs to generate a required output. Activities within WPIM contain one to many tasks. An instance of an Activity defines a cluster of tasks, e.g., an Activity can bundle tasks that are assigned to a single resource. Such an assignment can contain planning tasks that need to be executed by an expert (e.g., a planner) or tasks can also be assigned to a resource like a machine in order to represent the execution of a machine operation.

A **Task** structure is an action that cannot be further split into sub-actions. WPIM offers a semantic data representation to archive status and values when performing a Task. Such a Task can for example, represent an operation that can be executed by a machine and create a specified result. By having such a semantic representation containing incoming and outgoing status, progress attributes, as well as result specification, WPIM allows to delegate a Task instance to various executing entities. An example, in the context of planning tasks, is to finalize a plan by signing the plan and setting it into action. An Activity consists of at least one up to many Tasks. These Tasks represent the transformation of an input of the Activity into an output.

1.2.5 Semantic integration within knowledge-based information architectures

As outlined, e.g., in [15] data, information, and knowledge integration can be understood at varying levels of interoperability and heterogeneity. When trying to share distributed and heterogeneous data, a number of technical challenges must be overcome. Consider, for example, two systems having data sets that should be made interoperable. One can employ standards and technologies to overcome the various kinds of heterogeneities and to facilitate interoperability at different levels. System level interoperability can also be achieved at the grid or cloud service level. Grid and cloud services extend the basic web-service infrastructure and include additional features such as user authentication for secure data access. Apart from the generic issues of data access, transport, and remote execution, there are also a number of application specific system level issues, as, e.g., the choice and architecture of the mapping technology for the integration and mediation of information and knowledge resources (server-side, client-side, mixed). At the syntactic level, one has to consider heterogeneities such as different data file formats, depending on the type of content or knowledge resource and corresponding representation format of the information and knowledge representation. The Extensible Markup Language (XML) [16] provides a simple and very flexible syntax for structuring many kinds of data, metadata, content and knowledge resources to enable their exchange. For example, this can be done in different ways, e.g. in an XML ***Document Type Definition*** (DTD) or an ***XML Schema Definition (XSD, XML Schema)*** [16] [17] to specify the allowed nesting structure and (in XML Schema) the data types of XML elements. In this way, XML not only yields a data, information, content and knowledge resource exchange syntax but also prescribes a schema for the exchanged resource. However, additional explicit representations of semantics such as domain specific integrity constraints have to be encoded by other means. The ***Resource Description Framework (RDF)*** [11] can be seen as an XML dialect for encoding labeled, directed graphs and in particular ontologies as an example of a standardized semantic vocabulary. For querying databases and query languages, such as the ***Standardized Query Language (SQL)*** [18] for relational databases) or ***XQuery*** (for XML databases) [19] are used, each of which come with their own syntax for query expressions. Another important industry standard for ontologies is the ***Ontology Web Language (OWL)*** [20], which comes in three increasingly expressive variants: ***OWL Lite, OWL DL and OWL Full***.

1.2.6 Mediator Architectures

Mediators are a standard approach in the construction of information system architectures and are software components that serve to simplify, reduce, combine, integrate, and explain data. Mediators are mainly used for providing a common access level onto different distributed data sources. They have originally been introduced by Wiederhold in [14] as early as in 1991 when the web was still in its infancies and the semantic web did not even exist. However, since then the use and application of these architectures in building web-based information systems supporting, data, information, and knowledge integration has grown into a de-facto standard. Database mediator systems can be used to provide uniform access to distributed heterogeneous data sets, and thereby overcome a number of the interoperability challenges mentioned above. **Figure 2** depicts a typical mediator architecture in which a number of local data sources are "wrapped" as XML sources and subsequently combined into an integrated global view.

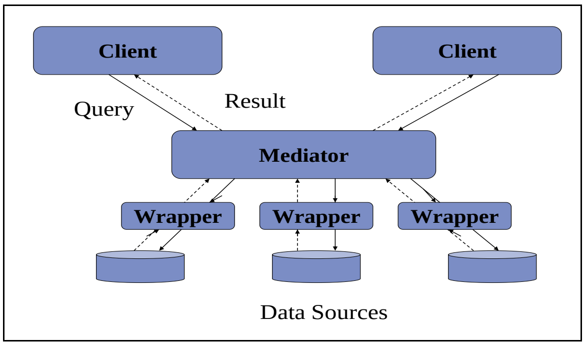

Figure 2. Mediator architecture integrating data sources

Thus, a client application or the end user is provided with the illusion of querying a single, integrated (or global) database with one integrated schema. In a conventional relational or XML-based mediator system, interoperability is facilitated at the structural level. Differences in schema can be overcome by corresponding schema transformation as part of the view definitions for the global view. However, terminological differences or other semantic differences are not adequately handled at the purely structural, e.g., XML level. To this end, source schema and contents can be registered to an ontology which encodes additional “knowledge” about the registered concepts. The task of the mediator is to transform queries to the global schema into queries to the local source schemata as well as to collect the results and to integrate and link them. The global scheme is based on a suitable data model, for which for example, XML or RDF can be used as representation. Wrappers are software components that represent the contents of a data source for the unification in another data model or schema. For example, XML wrappers are used to enable access to relational databases. The coupling between source and mediator via wrappers allows the mediator uniform access to the sources, by creating a mapping between the data model of the mediator and the data model of the local source. Also, incoming requests of the mediator can be translated into requests into the local source system.

1.2.7 Ontologies in Information Integration and Mediation

In information integration systems based on a mediator architecture, ontologies can be used to provide information at the level of conceptual models and terminologies. Thereby, facilitating conceptual-level queries against sources and resolving some of the semantic-level heterogeneities between them. In the original WPIM system the process classification ontology and the innovation ontology are used as a global view for registering process resources and processing queries. When a resource is registered to an ontology, a mapping from the data set to the selected ontology is generated. Wrappers use the mappings between the data source and ontology to translate queries from the global ontology to the local schema and also to translate content from the local schema to the global ontology. As explained above, the system can automatically use the subclass relation to expand concept queries when required. Note that although all system-registered ontologies can be considered as conceptual-level query mechanisms, the system can suggest suitable ontologies based on the one hand on the users’ choice of resources and on the other hand on the sources’ schema information. Database mediator systems can be used to provide uniform access to distributed heterogeneous data sets [15].

1.3 Knowledge-based Production Planning

KPP aims to combine and integrate distributed information and knowledge resources, e.g., about machine and tool descriptions, machining features, and process constraints in order to create an executable plan for a certain task. Such activities can happen within the boundary of one organization or even across organizational boundaries. The CAPP-4-SMEs project [1] explicitly has defined the goal to research in the field of CAPP, e.g., for the use case ***where Original Equipment Manufacturers (OEMs)*** work with global partners and suppliers which are usually mainly SMEs. In this way they can work more collaboratively to achieve an entire manufacturing value chain optimization [5]. KPP is based on all the presented technologies and combines all the advantages to one distributed and collaborative approach for production planning.

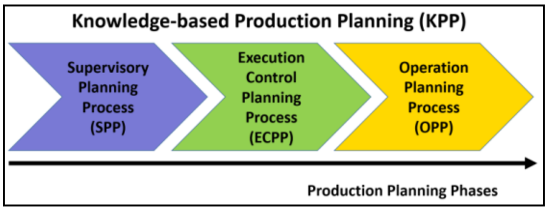

Figure 3. KPP method

Hence, it integrates the DPP planning process as well as the related resources with FBs and the semantic WPIM technology. The already presented steps of DPP were expanded and adapted to WPIM and turning **the supervisory plan** into an **operational plan** in an optimized manner. Therefore, as seen in **Figure 3**, KPP also consists of a three-level process model. In the understanding of WPIM, the DPP planning process and resource knowledge is represented by planning activities consuming and producing planning knowledge resources. These can, e.g., be FBs over all levels of CAPP activities from ***SP Process (SPP)*** activities through ***ECP Process (ECPP)*** activities to ***OP Process (OPP)*** activities. This is described in more detail in the related paper [31].

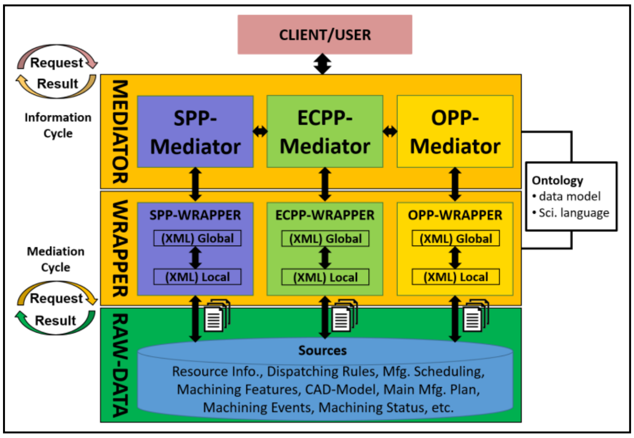

Figure 4. KPP Mediation Concept

The mediation process is also performed in a three-level MA. **Figure 4** displays this three level MA. The first mediator is called the ***SPP Mediator (SPPM)*** and integrates MFBs and other relevant and potentially distributed resources for the SPP activity. A down-stream DPP mediation can be implemented by means of two analogously derived additional mediators on the second and the third DPP level.

On the second level of the MA follows then the deduced and so-called ***ECPP Mediator (ECPPM)*** this supports the above-mentioned ECPP activity. They assimilated at least an earlier iteration of the SPP-mediator as MFB and an OFB of the subsequent OPP Mediator (level 3) and various other relevant and potentially distributed resources. Coming from the machining-data point of view, the corresponding up-stream mediation process starts from machines with a defined need of steering information, which can be harmonized by using wrappers and offering a mediated interface to clients. The third and final level of the MA of the KPP process forms the again derived ***OPP Mediator (OPPM)*** and completes the mediation process. This integrates relevant and potentially distributed machine resources as MFBs and by the second level generated EFBs (ECPP Mediator) for the OPP activity. This three-tier architecture can support an Information Process by, providing data from distributed data repositories, combining various data formats, in a single semantic enabled format, as well as a mediation process requesting, accessing and collecting/gathering/combining data from different distributed resources.

1.4 Conclusion

This paper has presented briefly the relevant State of the Art and summarized an overview over a method to support semantic knowledge management of DPP knowledge in the CAPP application domain based on semantic process representations producing and consuming function blocks and other relevant planning resources for distributed production planning. In this way, our approach will allow, e.g., SMEs to participate in a cloud based CAPP activity that is implemented on the basis of the DPP method. This is represented by the WPIM methodology in a machine readable way and where the distribution architecture within the cloud and beyond is achieved on basis of applying a three level mediator architecture.

As a further development of this work, our next step is to analyze a published White Paper, calls “Modern Production Planning Processes” [27] from the ProSTEP iViP Association [29]. This Paper is based on the ISO/DIS 18828 Standard [30] and presenting an end-to-end reference process that can be adapted to individual needs. This formal process, so called ***Reference Planning Process (RPP)***, is a recommendation and should cooperate with our approach. In addition, KPP applies even to another recommendation of ProSTEP iViP called "Manufacturing Change Management (MCM)" [28]. MCM deals with the management of changes during production and collaborates with the Production Planning Phase and vice-versa. We want to indicate possible matches.

Acknowledgements and Disclaimer

This publication has been produced in the context of the CAPP-4-SMEs project. The CAPP-4-SMEs project has received funding from the European Union's Seventh Framework Program for research, technological development and demonstration under grant agreement no 314024.
However, this paper reflects only the author's view and the European Commission is not responsible for any use that may be made of the information it contains;

References

[1] F. Miltner, T. Vogel and M. Hemmje; "Towards Knowledge Based Process Planning Support for CAPP-4-SMEs: Problem Description, Relevant State of the Art and Proposed Approach", vol. 1, International Manufacturing Science and Engineering Conference (MSEC), 2014.

[2] T. Vogel, "Wissensbasiertes und Prozessorientiertes Innovationsmanagement WPIM - Innovationsszenarien, Anforderungen, Modell und Methode,Implementierung und Evaluierung anhand der Innovationsfähigkeit fertigender Unternehmen", Dissertation, Hagen, 2012.

[3] L. Wang, G. Adamson and M. H. a. P. Moore, "A Review of Function Blocks for Process Planning and Control of Manufacturing Equipment", Journal of Manufacturing Systems, Vol.31, No.3, pp.269-279, 2012.

[4] L. Wang, W. Jin and H. Y. Feng, "Embedding machining features in function blocks for distributed process planning," *International Journal of Computer Integrated Manufacturing,* pp. 443-452, 2006.

[5] L. Wang, H. Y. Feng and N. Cai, "Architecture design for distributed process planning," *Journal of Manufacturing Systems,* pp. 99-115, 2003.

[6] M. Helgoson, L. Wang, R. Karlsson, M. Givehchi and M. Tedeborg, "Concept for Function Block enabled Process Planning towards multi-site Cloud Collaboration", International Manufacturing Science and Engineering Conference (MSEC), Vol. 1, 2014.

[7] International Electrotechnical Commission, Switzerland: Function blocks – Part 1: Architecture, IEC 61499-1, 2005.

[8] R. Lewis, "Modelling control systems using IEC 61499 – applying function blocks to distributed systems", ISBN: 0852976 796: The Institution of Electrical Engineers, 2001.

[9] International Electrotechnical Commission, Switzerland: Programmable controllers – Part 3: Programming languages, IEC 61131-3, 2003.

[10] T. Vogel and M. Hemmje, "Auf dem Weg zu einem Wissens-basierten und Prozess-orientierten Innovationsmanagement (WPIM) – Innovationsszenarien, Anforderungen und Modellbildung," in *KnowTech 2006*, Poing, CMP-WEKA-Verlag, 2006.

[11] R. Cyganiak, D. Wood, M. Lanthaler, G. Klyne, J. Carroll and B. McBride, "RDF 1.1 Concepts and Abstract Syntax," W3C Recommendation 25 February 2014, World Wide Web Consortium (W3C), http://www.w3.org/TR/rdf11-concepts/,, Feb 2014, accessed Nov 2014.

[12] W3C OWL Working Group, "OWL 2 Web Ontology Language Document Overview (Second Edition)," W3C Recommendation 11 December 2012, World Wide Web Consortium (W3C), http://www.w3.org/TR/owl2-overview/, December 2012, last accessed Nov 13, 2014.

[13] W3C, "OWL Web Ontology Language Overview,," World Wide Web Consortium,, 10 February 2004. [Online]. Available: http://www.w3.org/TR/owl-features/. [Accessed 14 November 2013].

[14] G. Wiederhold, "Mediators in the Architecture of Future Information Systems", The IEEE Computer Magazine, 1992.

[15] B. Ludäscher, K. Lin, B. Brodaric and C. Baru, "GEON: Toward a Cyberinfrastructure for the Geosciences—A Prototype for Geologic Map Integration via Domain Ontologies", Digital Mapping Techniques '03 — Workshop Proceedings, U.S. Geological Survey Open-File Report 03–471, 2003.

[16] T. Bray, J. Paoli, C. M. Sperberg-McQueen, E. Maler and F. Yergeau, "Extensible Markup Language (XML) 1.0 (Fifth Edition), W3C Recommendation 26 November 2008, World Wide Web Consortium (W3C)," http://www.w3.org/TR/REC-xml/, November 2008.

[17] S. Gao, C. M. Sperberg-McQueen, H. S. Thompson, N. Mendelsohn, D. Beech and M. Maloney, ""W3C XML Schema Definition Language (XSD) 1.1 Part 1: Structures", W3C Recommendation 5 April 2012, World Wide Web Consortium (W3C), http://www.w3.org/TR/xmlschema11-1/," last accessed Nov 13, 2014, 5 April 2012.

[18] J. Melton, "ISO/IEC FDIS 9075-1 Information technology - Database languages - SQL - Part 1: Framework (SQL/Framework), ISO Draft International Standard, ISO/IEC JTC 1/SC 32 Data Management and Interchange," http://www.jtc1sc32.org/doc/N2151-2200/32N2153T-text_for_ballot-FDIS_9075-1.pdf, last accessed Nov 13, 2014, August 2011.

[19] J. Robie, D. Chamberlin, M. Dyck and J. Snelson, "XQuery 3.0: An XML Query Language," W3C Recommendation 08 April 2014, World Wide Web Consortium (W3C), http://www.w3.org/TR/xquery-30/, April 2014.

[20] B. Motik, B. Cuenca Grau, I. Horrocks, Z. Wu, A. Fokoue and C. Lutz, "OWL 2 Web Ontology Language Profiles (Second Edition)," W3C Recommendation 11 December 2012, World Wide Web Consortium (W3C), http://www.w3.org/TR/owl2-profiles/, last accessed Nov 13, 2014, December 2012.

[21] ISO International Standard 14649-1:2003. Industrial automation systems and integration -- Physical device control -- Data model for computerized numerical controllers -- Part 1: Overview and fundamental principles. Geneva: International Organization for Standardization. Retrieved 2008-10-27.

[22] Lu, Yuqian und Xu, Xun. PROCESS AND PRODUCTION PLANNING IN A CLOUD MANUFACTURING ENVIRONMENT. Charlotte, North Carolina, USA : ASME 2015 International Manufacturing Science and Engineering Conference, 2015. MSEC2015-9382.

[23] Givehchi, Mohammad, Haghighi, Azadeh und Wang, Lihui. PaperGeneric machining process sequencing through a revised enrichedmachining feature concept. s.l. : Journal of Manufacturing Systems, 2015.

[24] Givehchi, Mohammad, Schmidth, Bernard und Wang, Lihui. Knowledge-based operation planning and machine control by Function Blocks in Web-DPP. Porto, Portugal : Flexible Automation and Intelligent Manufacturing (FAIM), 2013.

[25] X. Xu, L. Wang and Y. Rong. “STEP-NC and Function Blocks for Interoperable Manufacturing” IEEE Transactions on Automation Science and Engineering. Vol. 3, no. 3, pp 297-308. July 2006, Digital Object Identifier 10.1109/TASE.2005

[26] X Xu, H Wang, J Mao, S T Newman, T R Kramer, F M Proctor and J L Michaloski. “STEP—Compliant NC Research: the Search for Intelligent CAD/CAPP/CAM/CNC Integration”. International Journal of Production Research. Volume 43 no. 17, 1 September 2005, pp 3703 – 3743

[27] RECOMMENDATION - Reference process for production planning PSI8, ProSTEP iVIP, March 2013
http://www.prostep.org/en/medialibrary/publications/recommendations-standards.html

[28] RECOMMENDATION - Management of Changes during Production PSI12, ProSTEP iVIP, May 2015.
http://www.prostep.org/en/medialibrary/publications/recommendations-standards.html

[29] ProSTEP iViP Association e.V., https://www.prostep.org

[30] ISO International Standard DIS 18828-2:2015. Industrial automation systems and integration -- Standardized procedures for production systems engineering - Part 2: Reference process for seamless production planning International Organization for Standardization, Geneva, Switzerland (2015).

[31] B. Gernhardt, T. Vogel, M. Givehchi, L. Wang and M. Hemmje; „Supporting Production Planning through Semantic Mediation of Processing Functionality”, Vol. 1, International Conference on Innovative Design and Manufacturing (ICIDM), 2015, Auckland, New Zealand