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A MODEL FOR COLLABORATIVE PROCESS PLANNING IN A ENGINEERING AND PRODUCTION NETWORK

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ABSTRACT
Improvements in the agility of manufacturing systems in SMEs have promoted the emergence of collaborative engineering and production networks in which the partner companies cooperate to reach a shared objective. To date, much work has been undertaken to develop models and tools that facilitate hierarchical collaboration using concurrent engineering practices. In this paper a horizontal cooperation in process planning and among partners of a one-of-a-kind production (OKP) virtual enterprise is proposed. The Collaborative Process Planning (co-Planning) model enables the different participants to cooperate in three phases: Aggregate, Supervisor and Operational Planning.
*The result of co-Planning is a *onlinear Machining-Inspection Integrated Process Plan, which is obtained from a product model based on machining and inspection features. The co-Planning process is based on a representation supported by an integrated product-process-resource ontology. In order to establish the requirements of this ontology, this work provides the architecture, based on web services for an IT system to support the co-Planning process.*
Keywords: Collaboration, Cooperation, Process Planning, SOA

1. INTRODUCTION
Collaborative New Product Development (CNPD) is a process based on the practices of Concurrent Engineering (CE), through the formation of multidisciplinary groups and the use of IT systems to promote communication, coordination and/or cooperation (collaboration) between the different domains and activities of the new product development cycle. This process is especially important for the competitiveness of virtual OKP enterprises. The dynamic nature of these enterprises and the need for inter-domain and inter-company cooperation, inherent in this type of enterprise, mean they require CNPD systems that are adaptable and that have a high level of integration, both from a data perspective and from a user and communications perspective. From the work published in this area it would appear that platforms developed based on a Service-Oriented Architecture (SOA) and implemented using web services, are the most suitable solution for the construction of IT systems to support CNPD processes [1].
The CNPD process in OKP requires a high level of integration between the different subsystems linked to the Functional Design and Development of Products, Process Planning, and Production Scheduling and Control, and the implementation of a more intensive network to enable a high level of interaction between the participants to facilitate cooperative work. To enable an effective CNPD process in these environments, it is fundamental to design and implement a Collaborative Process Planning (Co-CAPP) system. This system must be capable of interacting with the other subsystems of the CNPD system and enable process plans to be defined based on the dynamic inter-enterprise and inter-domain collaboration processes, which are founded on the knowledge of the consortium.

This whole set of dynamic, hierarchical and cooperative processes, which are established around process planning, constitutes what we call the Collaborative and Integrated Development of Product, Processes and Resources (CIDP^{2}R) process [2].
The prototypes of collaborative process planning systems published in other recent works are generally founded on the division and distribution of tasks and their coordination using techniques for management of collaborative projects and/or document-centric workflows [5]. In contrast, Co-CAPP boosts cooperation in planning, which is understood as a horizontal collaboration to promote the interpersonal linkage in the group work belonging to the CIDP^{2}R process. Co-CAPP does this using interactive manipulation, discussion and negotiation mechanisms over a representation of the process plan that allows for alternatives (Non-Linear Process Plan, NLPP) and that is incrementally constructed. This is a focus that is quite well developed in the field of CAD applications but incipient in production planning [3]. The outstanding co-Design systems are ones that use features and/or assemblies representations, thus facilitating the integration of these collaborative systems with Co-CAPP, which also adopts this type of representation of the product.
In the following sections we present the functional architecture and the implementation architecture proposed for the development of the Co-CAPP IT system, which is made up of a series of application services and user applications that are the central module of a global platform for collaborative product development. The definition of these architectures is necessary to determine the requirements of a general product-process-resource ontology to support co-Planning, as described above, which is the main objective of the research work that we are carrying out on the COAPP project.

2. COLLABORATIVE PROCESS PLANNING FUNCTIONAL ARCHITECTURE

Co-CAPP is an integrated and collaborative system, designed to occupy a central role in the hierarchical integration between the Functional Product Design and Development and Production Planning and Control, which aims to define NLPPs represented as a global network. This network, which is described on three aggregate levels, is constructed in an incremental and cooperative way, by adopting different strategies. Thus the different manufacturing planners and specialists participating in group work carry out different actions in accordance with the permissions and assignments established by the project manager.
Before providing the functional architecture of Co-CAPP and the basic functionalities that support the three stages of Process Planning (aggregate, supervisor, operational) [4,6], we would like to describe the objective of each one and their interaction with the equivalent phases of Development Engineering (for Manufacturing) and the Configuration and Assignment of Resources (figure 1).
Aggregate planning establishes the macro-plan for the manufacturing/inspection of the piece, which represents the first level in the global network of nodes and relations and that will be detailed in the following stages. The basic nodes, which represent the aggregated processes (meta-processes), are associated with the nodes of the form and GD&T features tree at piece level and the nodes of the aggregated resources tree to form a global network on this first level. The restrictions established on the relations between the nodes define the alternatives of the NLPP at a meta-process level. The Configuration Development activity is where the tree of form and GD&T features is established. This tree describes the piece geometry and associated information at an aggregate level and in such a way that the feasibility of manufacturing and inspection on a meta-process level (e.g. forging, machining, dimensional inspection, etc.), also carried out as part of this activity, is enabled. Likewise, in the Assignment and Configuration of the Virtual Manufacturing System activity an aggregated resource tree is established, which describes the alternative configurations of cells or virtual groups that have the necessary capabilities and capacities to carry out one or more meta-processes. These cells or virtual groups, which may be made up of resources belonging to different companies, are configured with a process of negotiation and consensual decision-making among the companies in the consortium. This last activity has a close relationship to the Production Planning activities (materials, resources and orders) on a consortium level, and in turn interacts with the corresponding parts of each of the participant companies. The cooperation established around this activity enables the alternative configurations of resources that may be assigned to the meta-processes to be designed to fit the circumstances of production of the companies in the established timeframe.
In the Supervisor Planning the machining and inspection nodes break down into nodes that represent the processes of these meta-processes (e. g. face milling, CMM measurement, etc.) and that are

associated, in the same way, with the nodes of the trees that represent the resources (machines with their type of fixtures and tools) and the piece (machining/inspection features) in order to detail this level of the global network. As for the previous stage, the restrictions established on the relations at this level determine the possible process sheet alternatives, describing the sequences of operations that may be launched and that have the necessary information for supervision on a virtual cell level.

In Operational Planning, each of the operations (a process with a particular machine, a tool type and fixture type) identified in the supervisory level is associated with one or more working-step alternatives (in accordance with the STEP-NC standard, ISO 14649). We must remember that a working-step is a operation with a particular tool and fixture assigned. This whole set of working-steps corresponding to an operation is associated with a single feature (Operational Feature).

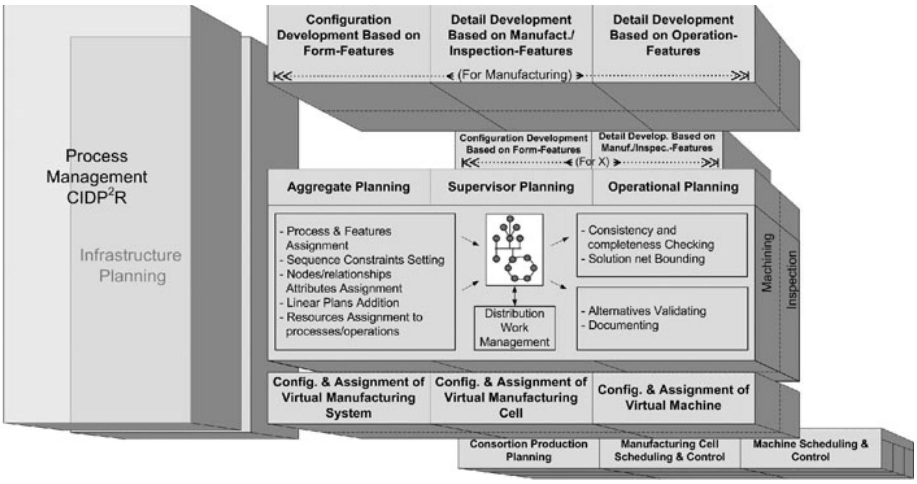

Figure 1. Functional Architecture of the CIDP^{2}R process

As is shown in the central part of figure 1, the group of functionalities provided by Co-CAPP for Process Planning is common to the three phases and has been designed for use in work procedures involving people cooperation. This general orientation of Co-CAPP, and specifically, of many of the functionalities of the Planning module that we just described, is compatible with the use of expert and/or optimisation functionalities included in legacy CAPP systems or forming part of itself.

This module provides anyone participating in the co-Planning process (in accordance with the permissions established by the project manager) with a whole series of functionalities that enable the incremental construction of the basic node structure (features, processes and resources) of the global network or of one of its parts (sub-networks), through additive actions performed using the assignment functions. The possibility of building sub-networks, which are built independently for later integration into the global network, is a mechanism that facilitates the carrying out of coordinated distributed work. Moreover, sequence constraints may be established over the relations existing between the individual and/or group nodes (groups of nodes of the same type and level).

Group nodes are built to facilitate the expression of restrictions, as the imposed by certain GD&T specifications and which lead the planner to group certain features for machining in the same set-up.

In the same way, attributes for cost, quality, time, and so on can also be assigned to the relations and network nodes, which will later enable comparisons to be made between alternatives with the aim of discarding the least suitable ones in accordance with the optimality criteria chosen. Additionally, to enable completely characterised and contrasted linear plans (full or partial) to be incorporated into the global network, the system includes the functionality of Linear-Plan Addition. Later, the global NLPP network obtained from the specification process described or that selected through the process of discarding solutions (Selected NLPP Net), must be checked to determine if it fulfils all of the rules defined to ensure the technological consistency of the feature-process-resource combinations represented and for the existence of at least one solution that enables the total piece manufacturing.

Finally, this module must also have: management functionalities (divide the problem into parts -subnetworks-, distribute and plan the work required for these parts, coordinate its execution, manage the NLPP structure, etc.); validate some of the chosen plans to check for fulfilment of certain requirements (costs, times, tolerances, etc.); and generate the necessary documentation.

3. COLLABORATIVE PROCESS PLANNING SERVICES ARCHITECTURE

Figure 2 shows the SOA-based framework of the Co-CAPP system, which is structured in three layers. The layers communicate through an Enterprise Service Bus, using SOAP and an information/knowledge exchange in OWL format. As can be seen in the presentation layer, Co-CAPP offers the services that support the work of four different team roles: NLPP viewer, Co-Planner, Cooperation Manager and Data Administrator.

This proposal has been developed with the aim of serving as a guide for the determination of the requirements that the technological platform imposes on the design of the integrated product-process resource ontology. The implementation of the CIDP^{2}R process as described above will depend to a great extent on the possibilities for representation offered by the ontology.

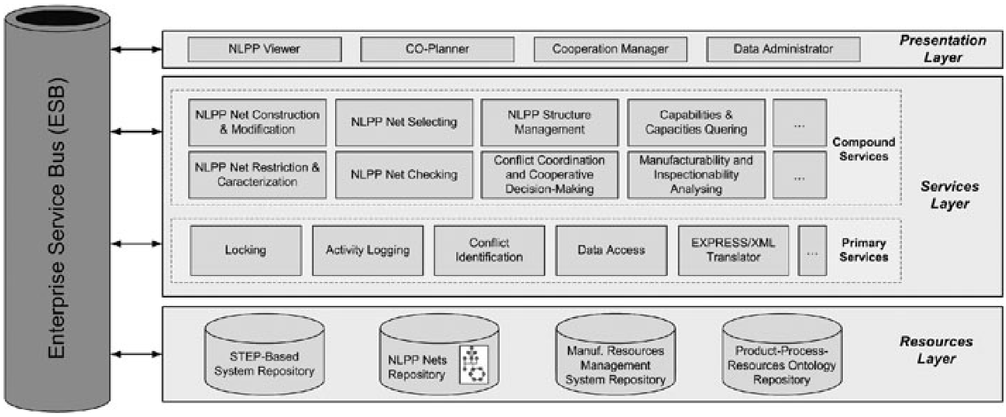

Figure 2. Service Oriented Architecture for Collaborative Process Planning

4. ACKOWLEDGEMENTS

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