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A FRAMEWORK FOR THE DEVELOPMENT OF AN IT PLATFORM FOR COLLABORATIVE AND INTEGRATED DEVELOPMENT OF PRODUCT, PROCESS AND RESOURCES

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ABSTRACT
In the present work, developed in the research project COAPP (Process Planning as a central element for concurrence and integration in engineering and manufacturing networks), we provide a framework for Collaborative New Product Development. This framework, focused on Collaborative and Integrated Development of Product, Processes and manufacturing Resources (CIDP2R) as a central activity interacting with the activities of Design and Production Planning and Control, takes advantage of current manufacturing paradigms, such as Agile Manufacturing, One-of-a-Kind Production (OKP) and the Virtual Enterprise (VE) as well as modern ICT infrastructures.
Additionally, the functional model and the service-oriented architecture of Co-CAPP information system are described. The adopted solution enable an inter-partner cooperative processes with high level of integration and adaptability.
Keywords: New Product Development, Collaborative Process Planning, Cooperative Processes.

1.. INTRODUCTION
Currently, small and medium manufacturing enterprises often need to adopt new models that enable them to operate in business networks, with product design and engineering chains, supply chains, and so on, which act towards their clients as a single entity (known as a Virtual Enterprise, VE).
Virtual enterprises take advantage of the latest developments in ICT to achieve a high level of integration, with an emphasis on distributed and collaborative work as a mechanism that affords them great agility. This agility is fundamental, above all, in companies involved in OKP that have adopted the model of a virtual OKP company. These companies are characterised by: their work in markets of customised products, which demands continual client interaction; right-first-time design and manufacturing; a product and production development with a concurrent and evolutionary focus; adaptive production planning and control; autonomous production departments, etc. In short, they have a great capacity to reconfigure and rapidly adapt their system to change.
This paper focuses on virtual OKP companies, which adopt a market strategy that focuses on engineering to order (ETO) and an engineering strategy that is product centric. To implement these strategies, the key is to boost what Buyukokan et al. [1] call Collaborative New Product Development (CNPD). This consists in applying the practices of Concurrent Engineering throughout the whole new-product development cycle, by the forming of multidisciplinary groups with participants from several companies who communicate, coordinate and cooperate (collaborate) in the different domains and activities of the cycle. A similar concept is Allied Concurrent Engineering [5], which proposes a process of distributed and collaborative engineering that is project based, product centric, and dynamically configurable, and that has a flexible, hierarchical, heterogeneous and recursive structure.

The environments and infrastructures needed in order to carry out high-level cooperative work, as is required in many CNPD activities, must enable frequent and dynamic interaction among partners, partner software system interoperability, partner information management, and cooperation coordination. These requirements and the dynamic nature of VEs have led to the need to adopt new proposals and directions in the design of web application platforms.

For CNPD in OKP manufacturing, it is essential to perform rapid product development and manufacturing, and this requires the establishment of high levels of integration and collaboration in Design, Process Planning and Production Planning. The central role of Process Planning in distributed and integrated environments has been mentioned or emphasised by different authors [4], but the development of cooperative CAPP systems has been very limited. To our knowledge the existing systems do not sufficiently exploit the knowledge of the experts in the different companies in terms of the possibilities of their manufacturing resources and processes. This knowledge is the foundation for assessing the manufacturability of designs and for establishing process plans to fit the available resource configurations and feasible resource assignments, depending on resources status and workload forecasts.

It is useful to remember that in other works, the concept of distributed activity or process is reserved for those activities or processes where team members do not share a common objective and work on separate parts, whereas in cooperative activities or processes team members share a common objective and work on the same parts, either synchronously or asynchronously [3].

This last concept, which is known as co-design, co-development, co-planning, etc., is the one adopted for the CIDP2R process, supported by the information system Co-CAPP. This is a system that centres on the activity of Process Planning and that operates in integration with the activities of Engineering Design for Manufacturing and Configuration and Assignment of Resources (Figure 1). In the following sections we give the functional model of the system, showing the central position that Co-CAPP occupies in CNPD, and the technological solution adopted for the collaborative platform on which it is implemented.

2. COLLABORATIVE PROCESS PLANNING IN PRODUCT DEVELOPMENT

Figure 1 shows the activities of the Co-CAPP system, which is designed for an OKP manufacturing environment. The aim of these activities is to generate a set of alternative process plans as a result of an incremental and cooperative action in which the experts from the different companies can incorporate knowledge of their manufacturing processes and resources. The main result of the application of Co-CAPP is a Non-Linear Process Plan (NLPP) containing all possible sequences of operations, where an operation is a process execution in order to obtain a feature or group of features using a particular resource or group of resources. These alternative process plans are described using a network of nodes (manufacturing and inspection) and relations with assigned constraints that limit the possible execution sequences. The nodes or groups of nodes in this network have association relations with the nodes of the structures that represent the configuration of the resources assigned for their possible execution (Resource Configuration and Assignment) and with the nodes of the feature trees that define the product (piece) from different perspectives and levels of detail. These relations correspond to the different processes involved (in our case, machining and inspection) and the different phases and steps of the design cycle in which they are used (e.g. Engineering Development-Detailed Design). The attributes and the rules, which can be assigned to any relation and node of the global network, allow to value the different sequences and to assure the coherence and completeness of process plans.

Co-CAPP is an integrated and collaborative system, made up of three modules, which occupies a central role in the hierarchical integration between Functional Design and Development of Products, and Production Planning and Control. Once the embodiment development activity has been performed on a piece level, which can be supported by a feature-based co-design system, Co-CAPP takes over the management of the CNPD process. This involves the following steps. 1) Ensuring that the piece manufacturability, using mapping of the form features and precision functional features and the association of these with manufacturing/inspection processes and resources with the required capabilities that are available within the timeframe of the manufacture of the piece (Engineering Development/Manufacturing module). 2) Specifying the global network of process plans (productprocesses- resources), resulting from a dynamic procedure to gradually develop the details of the plan, in different phases and steps. Here the actions that incorporate nodes (features, processes, resources) or groups of nodes impose sequential relations; perform cost, quality and time assessments for the different alternative execution sequences; and discard those that do not lead to a flexible overall solution or that are not within the imposed limits of the assessment (Process Planning module). 3) Ensuring that the assignment of individual resources or resource configurations is performed with attention to their capabilities, their availability time, logistical limitations, and the resource assignment policies established in the virtual OKP agreement. The network of plans establishes the alternative sequences of operations subject to the technological and availability restrictions of the established resources. This enables real-time Production Scheduling and Control based on the incorporation of time and/or opportunity restrictions, and where appropriate, optimality criteria. This activity should also be performed with a co-scheduling system, integrated with legacy systems for digital and virtual manufacturing, which are capable of obtaining real plant data and simulating future scenarios.

All of the above-mentioned functionalities of Co-CAPP and requirements for integration with other systems mean that we must have a representation of the network of alternative plans that have a wealth of semantic and logical information. This is difficult to achieve without a general ontology of product-processes-resources such as the one we are developing based on the PSL (Process Specification Language) ontology.

As can be seen in the figure 1, all of the execution activity performed in the Co-CAPP system must be supported by a process management activity (Process Management CIDP^{2}R) that schedules and controls the CIDP^{2}R process tasks and that also determines the infrastructure needs (information/knowledge, work teams and roles, and information system), to be handled in the infrastructure preparation activity.

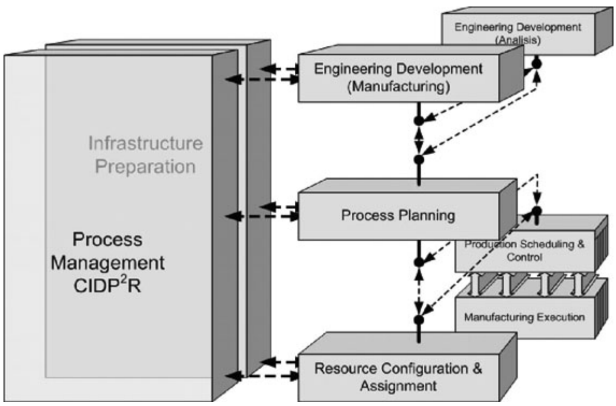

Figure 1. The CoCAPP system in the CPD process

3. INFORMATION TECHNOLOGY SOLUTIONS

In order to achieve the great flexibility and agility required by VEs and to efficiently support their characteristic inter-partner cooperative processes, there must be a high level of connectivity between all the components of the IT systems of the different partners. Thus it is necessary to align the structures of the different layers (strategy, business processes and IT systems) of the organisation by establishing a framework that enables the solution of the complex integration problems that arise on all of these levels.

In recent years the service-oriented paradigm has been used as an enabler in the implementation of IT platform frameworks to meet the needs of the new distributed and extensible systems that are characteristic of the different types of emerging enterprises (VEs, etc.). This paradigm incorporates the principles of structural decentralisation: loose coupling of the business units, which act autonomously, and complexity hiding through the use of uniform/standard interfaces.

This paradigm is based on service-oriented architecture (SOA), which aligns existing information systems with IT infrastructures, thus enabling a gradual implementation of its concepts in organisations. The central idea of SOA is the existence of services that give access to functionalities (capabilities) through well-defined interfaces, which are used under a contract with their restrictions and policies. This enables a loose coupling of services, which fulfils the principles of software engineering, information hiding and modularization. The services are reusable and can be made up of other already existing services.

Recently, this architecture has been adapted to facilitate the implementation of the e-Collaboration framework [2], offering extensible services integrated into platforms through which the different users can collaborate. Additionally, SOA is being implemented using Web services to take advantage of the great number of technologies and infrastructures that are already available for the Web; to break down technological barriers; to facilitate collaboration between people, groups, and so on; and to improve the interoperability between different single-user or collaborative information systems.

Thus, our idea is to construct an application that supports the CIDP^{2}R process, Co-CAPP, which will be a core module in a general collaborative development platform (for CNPD) where the application service layer (SOA) is made up of various application services (Figure 2). Collaborative application systems are made up of common collaborative services, which provide control mechanisms for concurrency, role management, negotiation and conflict management, data integration, etc., as well as other application-specific services. All of these collaborative systems (Co-Design, Co-CAPP and Co-Scheduling) and the Plant Knowledge Integration System, which models the process and resource capacities based on the data acquired in manufacturing (MES), are integrated through an ESB (Enterprise Service Bus). The ESB also enables the system to integrate the services developed with the wrapped services of legacy systems (CAD, CAPP, PLM, etc.).

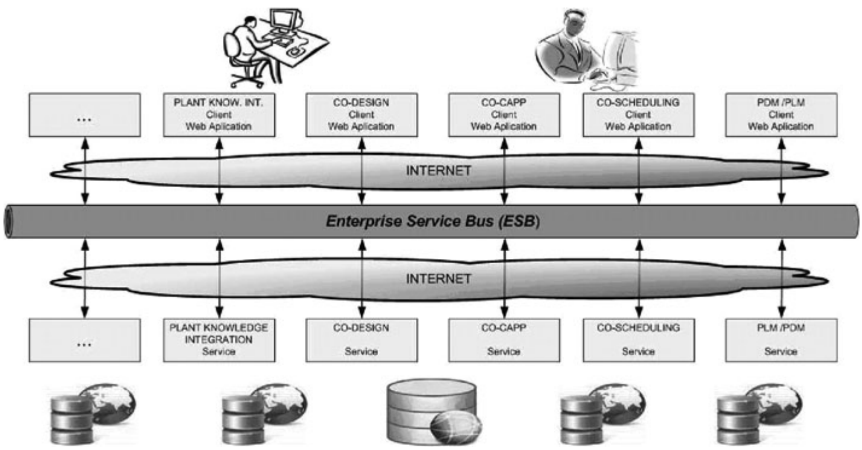

Figure 2. Service oriented architecture for a Collaborative New Product Development system

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