Co-Ordination Between Product and Process Definitions in a Concurrent Engineering Environment

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Received on January 7, 2000

Abstract

This paper deals with the necessary co-ordination among the designing team members in a concurrent engineering environment. It focuses on models and methods for co-ordination based on a co-operative work. The classical activity-based approach must be coupled with a professional-based approach to have a co-ordination system close to industrial practices. Then a first attempt to cluster the co-ordination methods of the literature in a specific typology is discussed.

Keywords: Design, Product model, Process model

1 INTRODUCTION

In a concurrent engineering framework, integrating the product and manufacturing process definitions plays a key role because optimising the product cost becomes possible. It is an economical challenge for enterprises. Many works consider this integration to reduce lead times of product development and therefore minimise induced costs. Decrease of lead time first comes from parallelism of the tasks of product and manufacturing process definitions. This overlapping of the two tasks is a main base for integration. It is now clear that quality and performance of product are improved when a co-ordination exists. So the product and manufacturing process parameters are harmonised since this design step and therefore industrialisation becomes simpler and faster.

The challenge is now to process and master the integration in the product development process.

The first level of integration concerns communication. Data can be exchanged among the professionals of the design process. Information must be put at the disposal of the professionals to help their own work to progress. It is essential. This permits to limit the multiple descriptions of product, and of course reduction of transfer errors, and also improve the global coherency of the description. This also permits to open to the public the work realised by and therefore make reliable information known at a given time.

The second level is co-ordination. The design process must be optimised by searching the best sequence of everybody's work. Most of the time, the best compromise between product lead time reduction and the availability of information ensuring certain reliability to results of the task. This level of co-ordination cannot be only seen as a problem of predefined division of activities to distribute human and hardware resources, cost and time. The strong interactions between mechanical engineering activities do not give an efficient robustness to such sequence. The professionals of the design process must also be co-ordinated by negotiation times to improve the effective design process in real time. So the third level of integration can be reached: it is really a co-operation activity.

The traditional questions of co-ordination must of course to be answered: What are the activities to be made in parallel? When must the activities be co-ordinated? What are the activities that must be effective to really gain in product development? But it is also necessary to question how this co-ordination must be efficient for professionals involved in the product development.

In this paper, this question is tackled through two models of co-ordination: a co-ordination by activities based on planning and monitoring, and a co-ordination of professionals based on negotiation and assistance to decision making (section 2). A typology of the mechanisms of co-operation in a product development process is proposed (section 3). Then the implementation of co-ordination in the integrated design system developed at 3S lab is discussed (section 4).

2 TWO FAMILIES OF MODELS FOR THE CO-ORDINATION OF THE DESIGN PROCESS.

Two approaches for the modelling of the product development process are proposed in the literature: a now classical approach based on the modelling of design activities and their interactions, and a new approach, more pragmatic, based on the network of professionals involved in the design process, using the intermediary objects. Those two approaches are complementary: the predictive activity-based approach becomes more realistic when the reactive professional-based approach is also processed.

2.1 Activity-based approach.

A design activity is both a functional entity and a singular element of enterprise services. Its properties are characterised by three factors: the structural organisation of the company, the goals to control the product development process and the level of granularity of activities needed. A design activity is a sequence or a combining of operations processed with a specific global goal, driven by certain input parameters and producing some output parameters.

Modelling the product development process mainly consists in creating a network of design activities optimising cost and lead time. It is based on two principles: parallelism and integration. Parallelism consists in simultaneously processing some design activities; it needs to decompose an activity into its component activities, and to maximise the overlapping of the design activities. Integration consists in considering constraints due to the whole product life cycle at the earliest design phases.

For example, a methodology for decomposition of the concurrent design process is proposed by Kusiak [1, 2]. It is based on two dimensions of decomposition: activity and constraint spaces. In the activity space, a one-mode incidence matrix is used to represent the dependencies between design activities. There are four types of dependency between activities: data dependency, control dependency, functional dependency and resource dependency. A two-mode incidence matrix is also used to minimise the "interaction density" among design activities. The analysis of the relationship between groups is required in order to reduce the interdependence and increase the degree of concurrency of the design process. The measure of the degree of concurrency is time-based and activity-structure-based. The shorter the duration of the design process and the lower the interaction density, the higher the degree of concurrency.

Decomposing the major design activities into design sub-activities can reduce the sizes of the working design groups and can have a dramatic impact on their performance. Groups in an activity involved in the design process allow one to determine a potential group of activities that might be performed simultaneously. The latter might reduce the design cycle. Another advantage of grouping activities is simplification of scheduling and management of the design process.

In such models, design activities are supposed to be process successfully. It is an a priori and predictive planning. The control is based on indicators on cost and time of every activity; the current state of cost and time is compared to reference cost and time predefined by the planner. Some authors attempt to introduce reactivity in those models to be more realistic and therefore take into account the stochastic nature of decision makings while designing [3].

2.2 Professional-based approach.

Jeantet proposes in [4] to analyse the design process through both the contents of the design project and the intermediary objects that make it clear. Tracking those objects shows on one hand the real network of professionals involved and on another hand the advance of the design process itself by processing modes, times of opening or closing, times for negotiation, uncertainty and decision making. In fact, the intermediary objects only exist by the design action: it is because they are related to the contents of the design project (for example, a representation of the future product) that they have legitimacy to co-ordinate the design professionals. They can support the co-ordination by three properties: translation, mediation and representation.

The translation operation consists not only in translating from one formalism to another the product definition but also in enriching the product definition by including the different points of view of the professionals involved in the construction of the object.

There are two mediation operations by the intermediary object. First of all, the object makes formal the current state of the design process at a time t, freezing for the time being this current state to propose it as a work base for the next design step. It summaries the previous design process. In another hand, it is a mediator by its status of object, which contributes to define the conditions of the interactions among the professionals; an object can favour prescriptive behaviours by its closure or co-operative behaviours by its capability to be shared. It can also be a border object to assist professionals in their local interventions, specific interpretations, and confrontations by proposing a joint reference. To favour co-operation among professionals, which are by nature heterogeneous with different cultures and expertise domains, a border object needs to be both adaptable to different points of view and robust enough to support the different professionals' identities.

The representation operation of a design intermediary object essentially consists in signs, models, simulations and figures. It only represents the part of the design process already performed. A real work of characterisation of the future product and of simulation of its behaviour has already been performed indeed but it has not integrated all the professionals' points of view necessary for the design process to be right performed.

The robustness of the proposal represented by the object therefore results from of course all the simulations done, but above all the robustness of the professional' network involved in the process and from which it has integrated constraints and additions.

It is the double dimension, capitalising the evolution of the design process and the distribution among heterogeneous professionals, which legitimates intermediary objects into co-ordination objects of the design process. They are provisional solutions, constantly evolving, assisting knowledge creation on the product and tracking learnings. They help professionals to express their conflicts and settled them by agreement.

The results of Vinck's analyses show that intermediary objects are good co-ordinators in a design process. You can see it a posteriori when you construct again the design process. The challenge is to create (may be from already existing objects) design objects, with the same properties as intermediary objects, in order to play the role of co-ordinators. Those new objects must be effective participants of the design process, accepted and validated by the professionals.

3 TYPOLOGY

A typology of co-ordination methods of a product development process is proposed here. It is based on four criteria related to the co-ordination activity. Eight co-ordination systems, extracted from the literature and our experience, have been analysed through those criteria. The names of the co-ordination system are ours and they will be referred by figures in parenthesis (see Table 1).

3.1 The co-ordination systems.

The eight co-ordination systems studied are the following. Information workflow (1) considers that an optimal solution of co-ordination exists. It is based on the analysis of the information workflow among the diverse design activities in order to propose a sequence of activities that minimises the lead time considering mastered risks accepted by the company. An example is given by Eversheim [5, 6]. Negotiated objectives (2) considers that efficient activities need a clear objective in order to have a result accepted by the concerned professionals. Examples are given by Brissaud on design and process planning [7] or Troussier on design and mechanical analysis [8]. Milestones (3) is a classical approach in project management. Bender identifies the critical parameters to discuss in rendezvous to argue solutions [9]. Professional rules (4) is based on DFMA methods and leans on the early integration of downstream constraints [10]. Mapped parameters or features (5) is concerned with the necessary coherency of parameters