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Supporting conflict management in collaborative design: An approach to assess engineering change impacts

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ABSTRACT

It is characteristic of collaborative engineering design that precedence relationships among design activities contain information flow conflicts. Due to multi-actors interaction, conflicts can emerge from disagreements between designers about proposed designs. Hence, a critical element of collaborative design is to manage the detected conflicts and particularly the impacts once they are resolved. Indeed, the conflict resolution comes up with a solution which often implies modifications on the product and the process organisation. This paper deals with the problem of conflict management process and particularly the impacts of changes once a conflict is resolved. First, a solution is proposed to assess the impact on the product data based on the concept of data dependencies network. Second, this paper quantifies key issues with regards to Concurrent Engineering that enables us to better manage the design process. Strategies to overlap coupled activities are proposed based on the dependencies between the handled data during the design process. Furthermore, prospects to effectively re-organise the execution of design activities are proposed. Key features for a better process re-organization are studied: *overlapping* rate and *multifunctional interaction* rate. The author examines, under varying uncertainty conditions, how these key parameters affect the process performance of product development time and effort. Findings and recommendations to optimise the process re-organisation are summarized.

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1. Introduction

Although in most design processes, coordination entails clear communication between designers, the real reason for this coordination is not for communication but for resolving dependencies between product data [1]. Design is constraint oriented, and comprises many interdependent parts. Designers must consider not only the functional requirements of a product but other aspects such as geometrical, behavioural and structural, among others. Each of these has its own set of constraints which may contain conflicting or unsatisfied requirements and designers cannot always oversee the various alternatives and constraints. Then, due to the multi-actors interaction, conflicts emerge from disagreements between designers about incompatible and interdependent proposals. A critical element of collaborative design would be the conflict management, which can be perceived as the succession of mainly four phases: conflict detection, identification of the conflict resolution team, conflict resolution, and solution impact assessment.

Several researchers have investigated conflict management in collaborative design, for example, Klein [2,3], Matta et al. [4], Cooper and Taleb-Bendiab [5], Lu et al. [6], Lara and Nof [7], and Rose et al. [8]. Most have proposed methods to support the conflict detection and the conflict resolution phases mainly. In a previous work [9], a solution called DEPNET[1] has been developed to address the problem of identifying actors to be involved in the negotiation process to resolve the conflict. However, the assessment of the selected solution impact, once the conflict is resolved, has not yet been tackled in the previous work. Consequently, the aim of this paper is to extend DEPNET in order to assess the impact of a selected solution on the product as well as on the design process organization.

The DEPNET solution is based on a process traceability system which explicitly captures and qualifies product data dependencies and inserts them in a dependencies network that is maintained throughout the design process. Based on this network, the conflict resolution team is identified to resolve this conflict. Indeed, conflict resolution cannot be achieved by one single actor since it requires

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[1] DEPNET—product specification DEPendencies NETwork identification and qualification.

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the interplay of different areas of expertise. To avoid iteration in the conflict resolution process, it is highly advisable to do it in a collaborative way that seeks the input of many actors to reach a consensus quickly. These actors refer to those designers producing the product data leading to the source of the conflict. In order to identify these negotiators, the data dependencies network is extracted and the product data, on which the source of conflict depends, are identified through network backtracking (the source of conflict being the starting point). A set of queries are then applied in order to identify the negotiators forming the conflict resolution team. Once the team is identified, they collaborate during a negotiation phase in order to come up with a solution to the detected conflict.

The negotiation leads to a solution which often implies changing one or more input data of the activity where the conflict has emerged, and thus, generating a cascade of modifications on the already produced data. The impact propagation is therefore highly dependent on the handled data during the design process. It supposes knowing the dependency relationships between the conflict source data and the data previously produced. Thus, it arises that propagating the selected solution impact mainly consists of identifying the dependency relationships between engineering data handled during the design process. Furthermore, the impacted data have to be redefined. This requires a re-execution of the design activities responsible on the elaboration of these product data and also an adjustment to the preliminary design process organisation.

In addition to the introduction, this paper consists of five more sections. Section 2 presents a literature review of previous studies on product data dependencies and product development organization relevant to the described research work. Section 3 illustrates the problem definition, using the example of a turbocharger design process. Section 4 focuses on the data dependencies network through describing the network nodes (product data) and network arcs (data dependencies). Section 5 illustrates, by means of a case study, the use of the DEPNET method during conflict management focusing on solution impact on product data. Sections 6 and 7 present a framework to first assess the solution impact on process organization, and second to study key parameters to optimize the process rescheduling. Finally, Section 8 summarizes the paper and discusses future research opportunities.

2. Literature review and discussion

The aim of this section is to review the related research literature in the areas of product data dependencies and design process organization. For this purpose, previous studies on product data dependencies are examined, and then a discussion how DEPNET differs from the studied literature is proposed. Second, previous studies in the design process organization area are surveyed. A discussion will follow in order to distinguish the proposed approach from other existing approaches.

2.1. Product data dependencies

Collaborative design is constraint oriented, and comprises many interdependent parts. A change in one part may have consequences for another part, and designers cannot always oversee these interdependencies and consequences.

Several researchers have investigated product data dependencies, for example, Eppinger et al. [10], Kusiak and Wang [11], Dong and Agogino [12], Wang and Jin [13], Browning [14], and Yassine and Braha [15]. Most of them have proposed a representation of product data dependencies (with a DSM matrix, a network or a set of patterns) but none has shown how to obtain these representations or proposed mechanisms to identify dependencies. In a comparative study of different visualization techniques (i.e. DSM,[2] change risk plot, propagation network and propagation tree), Eckert argues that "*there is no 'best' representation that is able to display all different aspects of change propagation properly and no one representation technique seems to be superior to others*" [16]. However, although DSM is used frequently to represent design, the author does believe that a graphical visualization is a representation that designers like to use.

Moreover, these studies have addressed the product data dependencies involved in a design process that has already been carried out, whereas the usefulness of identifying data dependencies is primarily during the design process ongoing. It helps designers to perform their activities and resolve interdependency problems. In addition to this reported work, all studies reported to date have only investigated the case of two dependent design activities (an upstream activity feeds product data to a downstream activity) belonging to the same decomposition level of the design process. For a complete identification of product data dependencies, it is necessary to consider the dependencies between activities carried out at various decomposition levels of a design process.

In terms of dependency qualification, some researchers have provided interesting proposals on this issue. The author particularly notes the framework developed by Krishnan et al. [17] to measure dependencies based on two dimensions: upstream data evolution and downstream data sensitivity. He also cites the work of Kusiak and Wang [11] dealing with qualitative dependencies (the direction of the change of product data that is affected by another) and quantitative dependencies (the rate of change of product data that is affected by another). However, these dependency qualifications and quantifications do not assist in identifying whether the dependency is strong and should be kept, or whether it can be removed. It should be highlighted that all of the previous studies have assumed the importance of qualifying product data dependencies but none of them has proposed mechanisms to support these dependencies.

Therefore, the DEPNET solution differs from the aforementioned studies in the following:

- It explicitly captures product data dependencies and inserts them in a dependencies network that is maintained throughout the design process.
- It proposes a method to identify data dependencies and defines concepts to qualify the discovered dependencies.
- It takes into account the pre-defined product data as well as the emerging data resulting from non-planned design activities.
- It considers the design process in a more realistic way and seeks to identify product data dependencies among sets of dependent activities belonging to various decomposition levels.

2.2. Product development organization

Given the vast literature on product development management (for an exhaustive survey, the author refers to [18,19] or [20]), the scope of this literature review is limited to facilitate identifying the research gaps. First, the author focuses on a particular class of models, *activity-based-models*, which view a project as a process decomposed into a network of activities. Thus, most *systems dynamics models* (e.g. [21]) are not included, which view a project as stocks and flows of generic work to be done. Nor *causal models* or *parametric models* are included, which might use techniques such as regression analysis. Second, in the survey presented in [20], four

[2] Design structure matrix.

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