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Performance evaluation of collaboration in the design process: Using interoperability measurement

Amir Pirayesh Neghab [a,*], Alain Etienne [a], Mathias Kleiner [b], Lionel Roucoules [b]

[a] LCFC Laboratory, Arts et Métier ParisTech, Metz Campus, France
[b] LSIS Laboratory, Arts et Métier ParisTech, Aix-en-Provence Campus, France

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ABSTRACT

A design process, whether for a product or for a service, is composed of a large number of activities connected by data and information exchanges. The quality of these exchanges, called in this paper collaboration, requires the ability to exchange useful, understandable and unambiguous data and information to the different designers involved. In this paper, a global framework is first set for process/product performance management. Then, the research question focuses on the definition and evaluation of the performance of collaborations, and by extension, of the design process in its entirety. This performance evaluation requires the definition of several key elements such as object to evaluate, the performance criteria, indicators and action variables. In order to define the object of evaluation, this paper relies on a literature study on collaboration resulting in an ECORE meta-model of collaborative processes. The collaboration performance measurement is for its part based on the concept of interoperability. This measure estimates the technical and conceptual interoperability of the different pairwise collaborations. The paper is concluded by proposing a tooled methodology for collaborations' performance evaluation including two main phases: process modeling and interoperability measurement. Tooling is provided through the Eclipse Modeling Framework (EMF) using its (meta-) model edition, constraint validation and model comparison features. The applicability of the methodology is also illustrated using a case study in design.

1. Introduction

Given the studies on product design such as [1,2], the goal of the design process is to develop a product that meets customer needs. Indeed, in this stage of the product life-cycle, the data, characterizing customer needs, must be processed in several artifacts in order to obtain knowledge concerning the product to design [3], and thus create one or more representations of the latter [4]. Howard [5] studies the phases and milestones of several design process, from the needs expressed to the product definition.

In the current design processes, collaboration is an intrinsic characteristic, particularly in the context of multidisciplinary design [6,7]. In fact, the design process is moving towards collaborative design process, which requires and encourages collaborations between designers from the beginning of product life cycle [8]. According to [9,10], there exist a plethora of collaboration definitions describing several types of interactions. These interactions in the design process mainly occur when designers communicate the results of their activities that support product data exchange [11,12]. According to Chiu [11], communications and data exchanges are prerequisites for collaboration. In addition, the author did an experiment in an academic environment that indicates that the designers have spent almost half of their time focusing on communication. It is also stated that effective communication is critical to the project participants of collaborative design.

It is observed that designers may encounter problems in their collaborations such as technological problems in data transmission or in understanding the transmitted data [13]. According to [17], some of these problems, particularly the different interpretations of data, are results from the use of this data in heterogeneous environments. These heterogeneities are based on the differences between computing environments, languages, techniques, tools [14], and data sources [15,16], in different areas of expertise. Such heterogeneities are noted by [17], [18] and [19] as sources of problems in collaborations. The heterogeneity problems often cause irrelevant [20], inadequate, imprecise or ambiguous data [21,20]. These problems might also cause failures in the individual tasks of designers [22]. This is the reasons why for more than a

* Corresponding author. Tel.: +33 685231328..
E-mail address: amir.pirayesh@gmail.com (A. Pirayesh Neghab).

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decade, a large number of references indicate the need for studies on collaborations and the management of their performance [23–25], Despite these indications, very few theories explain how to manage such performance particularly in a situation where information plays a key role [26].

The word performance can be applied in different terms, such as "performance management", "evaluation or measurement of performance" and "performance assessment" to describe the process of capturing performance [27]. In this paper, the research approach is built around the key elements that form a problem of performance evaluation. Based on [28], it is considered that the evaluation of the performance of an object (e.g., a company, a design process or a product) comprises the following elements: criteria, indicators, action and measurement variables. Among these elements, the criterion choice plays a significant role since it reflects the objective of the evaluation. The performance assessment can be based on classical criteria such as cost, time and quality; in this paper, considering the significance of collaboration, it is decided to retain a criterion that intrinsically belongs to this concept and addresses the quality aspect of collaboration (see Fig. 1). This criterion is called Interoperability.

Several classifications and evaluation approaches of collaboration were studied to identify such criteria. Husted and Michailova [29] classify collaboration as: infantile, repeated and mature based on collaboration history, where some classifications address the collaboration results. In these classifications, the collaborations can be successful, significant and strong or failure, non-significant and weak [30–33]. The third category of classification provides one or more criteria based on the difficulties encountered by collaborative actors. For example, Girard [34] classifies collaboration as: free, encouraged or forced based on the freedom of actors to collaborate. Indeed, in this classification, organizational difficulties (i.e., authorizations and motivations) are underlined. It is observed that the classifications and assessment approaches, such as [35,36], which are based on a criterion called "Interoperability", are more suited to evaluate the collaboration performance. In fact, this concept covers a larger spectrum of capacities required in collaboration. Regarding the definitions proposed by [37,38], the goal of interoperability is to overcome the problems in data exchanges [22].

In this paper, in order to clarify this concept with the objective of finding at least one of its indicators, the Chen's framework is adopted [39]. This framework, as illustrated in Fig. 2, structures interoperability in three dimensions: Interoperability barriers, concerns and approaches.

Concerning the first two dimensions of Chen's framework, this paper studies the technological and conceptual barriers of interactions of the type data exchange between designers. This paper also addresses the third dimension since any interoperability approach or solution, applied in a collaborative process, should be identified and studied in the evaluation of the collaborations' performance. This scope is located in Chen's framework (see Fig. 2). Considering this scope, the present paper focuses only on the problems of data adequacy. According to [26,40] such problems are in expansion. In this paper, it is primarily considered that the data are always produced correctly and are understood by the

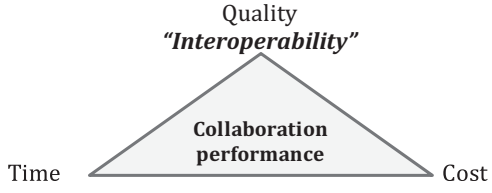

Fig. 1. Interoperability as the criterion of collaboration performance evaluation.

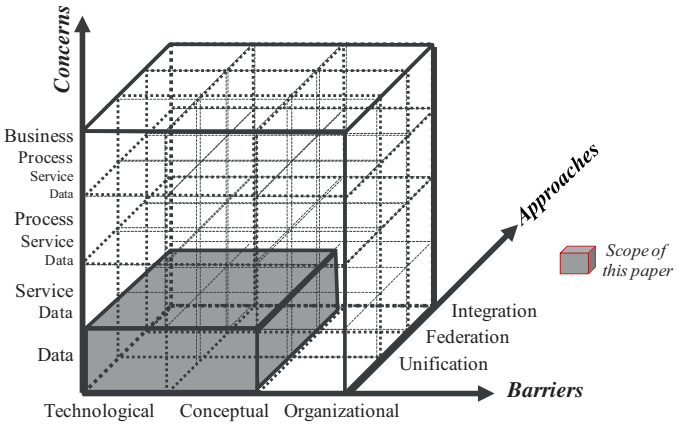

Fig. 2. Scope of research questions according to Chen's framework [39].

designers. This assumption allows to better focus on the inadequate data since this problem is dissociated from the accuracy and comprehensibility problems. *Data adequacy* is then considered as an indicator of interoperability. Here it is considered that this indicator reaches its maximum value when the data produced by the actors: (1) can be accessed by others (this condition corresponds to the technical aspect of this indicator), and (2) are sufficient and useful for the others. This condition corresponds to the semantic aspect of this indicator.

The design process in this paper is considered to be in its evaluation and validation phase. Therefore, the objective is to evaluate this process before its execution. In this case, only the backbone of the process, including the sequence of activities and resources, is available. In such process, product data are not yet instantiated. However, some information is available on them: *file exchange formats* and *file abstractions* (the file contents and structure of data) in case of availability of these abstractions. The extraction of the abstraction is usually a tedious or impossible task, especially when the format is not open or is not based on an open standard. Therefore, this paper is limited to the terms used for file formats when the abstractions are not available. Having this information on the data files, *data adequacy* conditions are translated as the Compatibility of file formats and contents.

Considering the fact that in this paper collaboration performance is defined as the ability of actors to exchange adequate data, the following questions are raised here: is it possible to quantify and improve the collaboration performance? How the latter is affected by the elements of collaboration (actors and their resources) or by their heterogeneities? Facing these questions, it is first considered that collaboration performance, as a part of process performance, impacts product performance. Such impacts are mentioned previously in the field of risk analysis, particularly in [41,42], which study the links between process and product performances based on product failures.

As illustrated in Fig. 3, the performance evaluation based on Interoperability (i.e., 1a) and the parallel evaluations based on other criteria (i.e., 1b) can be positioned in a global framework supporting the management of the design process. This framework is founded on the link between the results of the process and product performances through *product failure analysis* (i.e., 2). This analysis shows that all the results of process performance evaluation can be analyzed by focusing on the problems causing product failures. In the *generating* step (i.e., 3), alternative processes can be generated by modifying the elements of collaborations identified as critical in the previous step. During the *selection* step (denoted 4), an optimization model is used to maximize the value of the product. Considering the Fig. 3 and