Management of heterogeneous information for integrated design of multidisciplinary systems

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Abstract

Multidisciplinary systems (such as Mechatronics or Cyber Physical Systems) are considered as the resulting integration of design expertise from several disciplines such as electrical/electronic, mechanical and computer sciences. As a result, a large number of design data, such as software code, CAD models, 0D/1D and 2D/3D CAE results, etc. are generated by designers and heterogeneous computer-based tools throughout the whole development process. Therefore, effective exchange between designers from different disciplines is required in order to achieve multidisciplinary integration. In order to insure knowledge sharing between the designers issued from the different disciplines, the heterogeneous information from previous design projects could be captured, elucidated and managed by designers.

In this paper, after presenting the multidisciplinary integration during the system design, the importance of effective exchange between designers from different disciplines is highlighted. In this paper, after presenting the multidisciplinary integration during the system design, the importance of effective exchange between designers from different disciplines is highlighted. Then, the existing techniques related to the capture and management of heterogeneous information are introduced. Afterwards, an approach helping designers to capture the design data issued from CAD models and 0D/1D and 2D/3D CAE results, is introduced. Finally, the conclusion is drawn and future work is pointed out.

Keywords: Knowledge Based Engineering; Collaborative Design; Data extraction; Mechatronics; Cyber-Physical-Systems; Routine Design

1. Introduction

This paper gives an overview to a knowledge-based engineering (KBE) approach developed for an ongoing research project, focusing on multidisciplinary engineering knowledge capitalization. The information captured from past projects is then stored in an agnostic knowledge solution based on parameters and rules. This work aims to present the extraction process and the semantic issues related to the data processing step.

The following section presents the context of our work. A part of the research work is focused on the design of multidisciplinary systems such as Mechatronic and Cyber-Physical-Systems products in a routine design context [30]. This section also presents the objectives and the problem statement.

The third section investigate the state-of-the-art of heterogeneous data and highlight the fact that, up to present, most studies were focused on the extraction of a domain specific data. Then some techniques are discussed to solve semantic problems in a specific area and is enlarged to multidisciplinary concerns.

Next, the proposition on two different aspects is envisioned. The first aspect is on the identification of six cases of semantic problems and their characterization. The second is our core proposition represented by a general process of extracting and processing heterogeneous data from various sources: Computer Aided Design (CAD) or Digital Mock-Up (DMU), 0D/1D and 2D/3D simulations which are stored into Information Systems (IS) called “third-parties systems”.

Finally, a conclusion summarize our proposition and future work for our research project is exposed. An acknowledgement.
will thanks our industrial and academic partners for their respective contribution.

2. Context

Our work is focusing on developing an approach for an ongoing research project called MiMe including academic and industrial partners. This acronym stands for “Module d’Intégration et de Simulation pour la Mécatronique” (Simulation and Integration Module for Mechatronics). As specified in the acronym, this work focuses on mechatronics. Mechatronic products can be defined as “the result of combining the engineering disciplines mechanics, electrics, electronics and IT”. This requires coordinated trans-sectoral cooperation from the people developing the product as well as from the organisational unit [1].

Although, to enlarge the scope of our work, Cyber-Physical-Systems (CPS) are also considered. CPS are defined as “physical and engineered systems whose operations are monitored, coordinated, controlled, and integrated by a computing and communication core” [23].

Mechatronics and CPS are two classes of what are called “multidisciplinary products” [11,32] whose main characteristic is to be developed across different disciplines. These classes of products are becoming more and more complex to develop [31]. Collaboration and integration are unavoidable points in this area and attract attention of both academia and industry [12].

Modern industry is facing ever increasing challenges of more complex products and even sometimes geographically dispersed design teams. It is likely that different design teams use different terms to represent the same information according to their own expertise and discipline, which yields confusion during the collaborative design activities of such complex products. For example, one design team use the unit “degree” to describe the angle while another use “radian”. Specifically, this multidisciplinary context involves the use of various Computer Aided Engineering (CAE) software - at least one or more disciplines and their associated models. These models often contain engineering data in a heterogeneous form that our work aim to extract, process and pour into a knowledge data base for a further use. Heterogeneity is used to characterize data that originate from different sources (CAD, Computer-aided manufacturing, Simulation results, technical metadata, etc.), that could be from different types (physical magnitudes, texts, images, videos, etc.) or by their format.

The concern of a further use is mainly applicable in a routine design context. In a routine design context [30], as opposed to an innovative design context, each project has similarities with previous ones. A capitalization from previous data is thus a possible manner to reduce development time, cost [24] and risks. As a consequence, a KBE approach is a potential solution to capitalize data from past project. Although, most KBE solutions are only structured data based those that are sometimes integrated in a PLM. This article will propose an approach to support extraction process to complete a knowledge data-base from heterogeneous data.

In the context, these heterogeneous data will be extracted from different software, different disciplines and different teams or companies. As an observation, the technical lexicon could change between companies, teams, software, disciplines, etc. Besides the complexity of the multidisciplinary product development, the way to extract data also leads to semantic issues such as misunderstandings. This statement could be a real problem in a collaborative work. The use of different words to characterize the same object for example can impede the collaboration and make it unclear. In most cases humans are able to recognize semantic problems, but it is envisioned to automatize this process through a semantic dictionary.

Our objective is to allow companies that mainly work in a routine design approach to capitalize data from their past projects, focusing first on CAD/DMU, 0D/1D simulations and 2D and 3D simulations. These data are part of the third-parties systems. To achieve this objective, a bridge, represented by our process, will be built between these third-parties systems and the agnostic knowledge base. Agnostic is defined as an adjective “denoting or relating to hardware or software that is compatible with many types of platform or operating system” [22]. The multidisciplinary context and the data heterogeneity from many sources entail to be agnostic and is as a consequence wanted to be free from a specific software editor.

The second objective is to define a semantic dictionary to identify and converge technical terms to improve and ease multidisciplinary collaboration. This second objective support the first exposed above. Next section presents the related work which can partially achieve the two objectives.

3. State-of-the-art

The first objective of the research work is to help designers to extract data sources stored by third-parties systems. The research context presented in Section 2 reveals that the various third-parties systems have been involved during the design process of the so-called multidisciplinary products. Increasing number of data sources are generated accordingly. Therefore it is significant to develop a bridge which can connect the third-parties systems and the knowledge base so that designers can extract the heterogeneous data from the diverse third-parties systems and store them in the KBE system.

KBE is a technology based on dedicated software tools, which is able to capture and systematically re-use product and process engineering knowledge, with the final goal of reducing time and costs of product development [25]. How to extract the heterogeneous data sources and store them in the knowledge base is a subject of increasingly interest both of both academia and industry. Extraction of heterogeneous data sources to support collaborative activities has been studied for long time in the discipline of computer science. According to Batini et al, name heterogeneity is the most common type of semantic heterogeneity [2]. Name heterogeneity refers to the conflicts of terms used to describe different data source. Castano and Antonellis propose a global view that can provide a unified representation of the information in the different sources [4]. Rouset and Reynaud develop an information integration system which provides a uniform query interface to collection of distributed and heterogeneous information sources [26]. In their proposition, the data of the World-Wide Web which are
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