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Toward a methodological knowledge based approach for partial automation of reverse engineering

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Abstract

Nowadays, reverse engineering is widely spread in the manufacturing industry. The need of shorter development cycles has led to the identification of social and economic issues related to reverse engineering. The integration of a reverse engineering solution in a PLM context represents a good solution in order to shorten the development cycles, especially when it is automated. In this paper we present the issues identified in the context of METIS, a French national project aiming to provide a software solution for reconstructing large and complex mechanical assemblies and systems, through a global reverse engineering methodology combined with a knowledge management approach, and using heterogeneous data as inputs.

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Keywords: Reverse engineering ; Knowledge management ; Heterogeneous data integration; PLM.

1. Introduction

Reverse engineering has been developed as an alternative solution to define or redefine objects [1]. Nowadays, it is widely spread in the manufacturing industry. It is used for the capitalization of information and knowledge, which haven't been collected yet. This is a critical issue for the development and evolution of products. We can list some of its applications in industry: long life products maintenance (trains, boats, aircrafts, nuclear power plants, etc.), redesign of existing products in order to improve them, competitors' products' analysis…

In the manufacturing industry, there is an amount of social and economic issues related to reverse engineering and its integration into the digital chain in a PLM context: shorter development cycles which lead to a drastic reduction of costs, a simplification of knowledge management related to the projects…

However, the major industrial issue lies on the improvement of existing solutions in order to respond to generic use cases [2]. The use of raw data such as digitized objects as only inputs is not sufficient to build a robust reverse engineering process. There is a need to consider the implicit and explicit knowledge. On top of that, to increase the efficiency of the process, the automation of the process has to be considered in order to address the issue related to shorter development cycles.

This paper will address the development of a reverse engineering solution partially automated, through a knowledge management approach in order to develop a generic knowledge-based reverse engineering methodology. This methodology can be adapted to different reverse engineering contexts of use, and enables lead to rich results integrating different points of view in order to increase the redesign efficiency of complex assemblies, while being fast since it would be partially automated.

After the description of the context of the research work in section 2, section 3 deals with the problem statement, while section 4 presents the proposed scientific methodology. Finally, the last section introduces the METIS project that is the application of this research.

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2. About Reverse engineering and knowledge management

2.1. Reverse engineering

Reverse engineering is the reverse process of the design activity. It basically consists on the reconstruction of design models associated to a real product [3]. The main goal of the reverse engineering is to go back to the results of the original design process in order to create a copy of the product, as shown in the figure 1 [4]. To do this, the reverse engineering process uses the knowledge extracted from the real product's characteristics analysis, combined with knowledge that concerns the manufacturing process.

Nowadays, there are several solutions dealing partially with this topic [5] [6], mainly working on the geometrical aspect of the product. In general, there are 4 main actions that are identified in the reverse engineering process [7]:

- Product scanning and data acquisition.
- Segmentation of the acquired data.
- Knowledge extraction (i.e., feature recognition).
- Reconstruction of the 3D model updated.

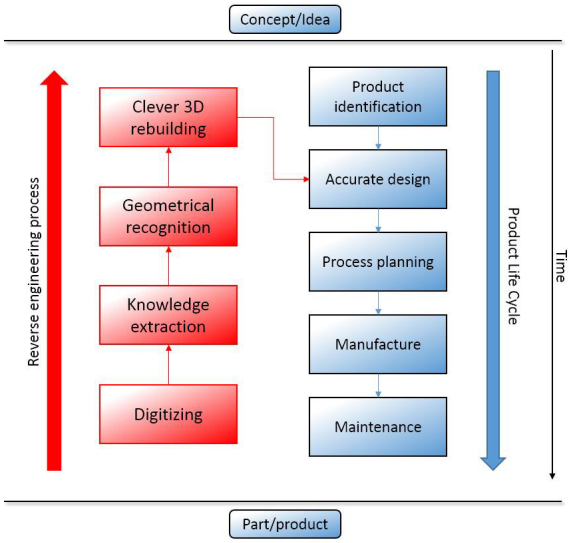

Fig. 1. The reverse engineering process connection with the product development cycle [4]

However, those approaches do not take into account the implicit and explicit knowledge related to the products, and the 3D models are frozen and do not allow flexibility. In other words, the parameters, the relationships, and the constraints that materialize the design knowledge within a 3D model are not available.

In general, research works related to reverse engineering are essentially focused on mechanical parts starting from 3D points clouds. The aim is often to recover a digital mock-up. There are several solutions that allow knowledge extraction from data. For example, in figure 2 is illustrated a solution for the association of features with points clouds [8][9] (Figure 2).

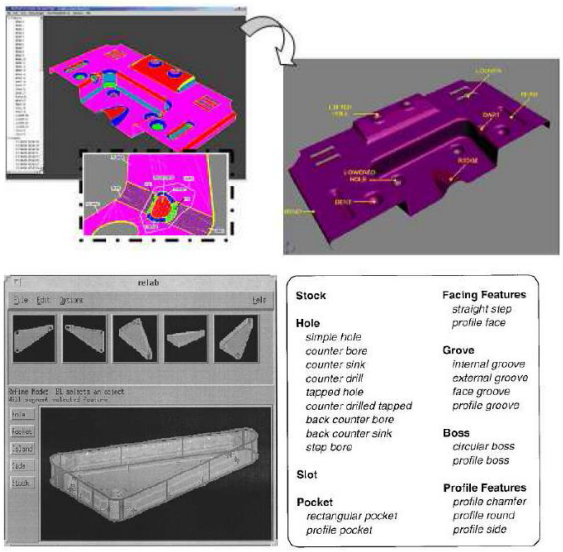

Fig. 2. Entity extraction systems. Top: Sunil & al. [8], bottom: Thompson & al. [9].

Another example is the VPERI project [10], which aims to build methodologies, tools and technologies in order to make viable and maintain systems already designed. The reverse engineering process is supported by the ASU-DAL CAD platform that allows the additions of comments virtually written on the heterogeneous data (Figure 3).

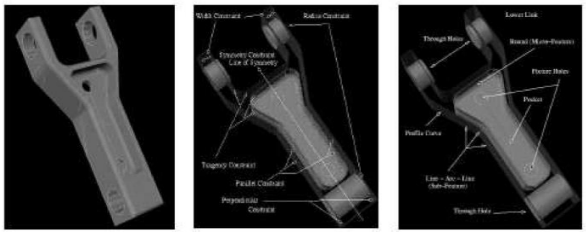

Fig. 3. Sample of the ASU-DAL interface a part [10]

In the project MERGE, the system provides a single collaborative platform in order to visualize information [11].

Acquire and process product knowledge is important to obtain a rich digital mock-up. A solution based on the functional diagram block (APTE – requirements analysis) brings to light the different flows related to the product [12].

All of those methodologies offer few possibilities of automation for the reverse engineering process, or freeze the digital mock-up, and do not consider the implicit and explicit knowledge. In fact, in the case of the VPERI project, reverse engineering is interactive but very manual, thus, tedious.

The PHENIX project brought into evidence this lack [7]. The PHENIX approach proposes a knowledge management solution in a PLM system. In this case, the reverse engineering process became partially automated, where the user selects the entities corresponding to the studied component while browsing an entities database. However, PHENIX can process only points-clouds as inputs and reverse engineer components