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Method for automated structuring of product data and its applications

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Abstract

Product structures represent the data backbone for through-life management of complex systems. Product Lifecycle Management (PLM) Systems are used to maintain product structures and track product changes. However, in maintenance, repair and overhaul (MRO) product composition often is unknown when MRO service providers are not the original manufacturers. Thus, MRO processes start with an exhaustive product diagnosis to identify elements to be maintained or replaced. Existing 3D scanning and data post processing methods have to be improved to acquire structured product data. This paper presents a method for automated derivation of product structures from 3D assembly models.

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Keywords: Product structure; graph theory; product data management; reverse engineering; 3D scanning

1. Introduction

Product data is essential for efficient through-life engineering services, since it is the basis of any systematic maintenance, repair and overhaul (MRO) planning and operation. However, life cycle based documentation of changes regarding product configuration, condition and functionality is still an unsolved problem for holistic product life cycle management approaches [1]. Consequently, MRO service providers have to diagnose characteristics individually for any specific product. Each life cycle stage modifies the product structure: Stages to distinguish are design (as-designed), production (as-produced), use (as-used), MRO (as-maintained) and recycling (as-recycled). Change notification is not shared in B2B and B2C networks due to reasons of intellectual property, quitted businesses or data conversion problems in incompatible or aging IT infrastructure. Efficient data reconstruction or retrieval strategies are needed for fast product diagnosis and documentation. These strategies comprise reverse engineering of 3D models for overhaul projects [2]. 3D models and other product data required for MRO activities can be managed in PLM-Systems. Today's PLM-Systems are not restricted to the creation of products, but can be used for spare part management, reengineering processes, asset management and many other MRO-tasks. The product structure forms the data backbone of these PLM systems. Hence structured storage of data generated within MRO activities is inevitable.

This paper deals with structuring of geometric product data coming either from a reverse engineering or a forward CAD modeling process within MRO processes. A method has been developed for visually and algorithmically assisted structuring of product models. The semiautomatic process uses a 2D-contact graph which is derived from a 3D-model by a neighborhood analysis to identify logical groups for building a structure. Data transfer of structure information is performed by a PDMXML file. Industrial benefits may be to reduce the effort of structure management divisions within the product engineering areas of large companies. Although this paper addresses especially the through-life engineering topic the solution approach is also relevant for the design stage within the product creation process.

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2. Initial situation and state of the art

Currently there is no approach for automatic identification of product structures for 3D product models without a given assembly structure available. If structured product data is required within a MRO process (as described in chapter 4), comprehensive knowledge on the respective product is needed to manually model a proper product structure [3]. In many cases this knowledge is not available, especially in cases of long-life systems and for third party service contractors.

Research on Reverse Engineering and reconstruction of mechanical products focuses on recognition of single surfaces rather than on whole assemblies and its product structures. Principles are based on basic primitives like spheres, cylinders, cuboids [4] or other features and constraints [5]. Segmentation methods are used to detect edges and surfaces [7,6]. The goal of reconstructing whole industry sites or buildings including single object information is pursued by Building Information Modeling (BIM) applications. Complete elements of the structure are virtually rebuilt and component lists can be created [8,9]. However, despite semi-automated features for reverse engineering effort is still high [12,11,10].

For the understanding of the presented method and its benefits regarding the current practice of generating structured product data in MRO processes two questions have to be answered:

1. What is the output of 3D scanning?
2. How are product structures generated?

2.1. Output of 3D scanning principles and post-processing

The result of a 3D scan is a point cloud which includes x-,y-,z-information as well as a normal direction. Standard software creates a mesh or polygon surface. Due to limitations of visibility or difficult capturing of shiny or concave surfaces the resulting mesh may be incomplete and may show artifacts. Usually manual post-processing of these meshes with suitable software features is performed. There are several data formats for polygon models such as STL, PLY, OBJ or WRL. For CAD modification a further processing step called surface reconstruction is necessary. The results are Non-Uniform Rational B-Spline (NURBS) surfaces.

Reverse engineering of assembly models consisting of single parts is done as follows: First, a 3D scan of the complete assembly is performed. Then, the physical assembly is disassembled and 3D scans have to be made of each single part. Finally, the resulting 3D polygon models are referenced to the initial 3D scan. This is possible with special reference markers that can be stickers put onto the object's surface. Creation of CAD assembly models is more elaborate. The single part's 3D polygon models have to be reverse engineered to surface models respectively CAD parts. These CAD parts are assembled in a CAD tool by visual comparison with the physical model. There is no difference or advantage to the forward engineering process. In previous research an enhanced reverse engineering process has been presented to automate reverse engineering of assembly models [2].

2.2. Generation of product structures

A given set of product parts can be classified and structured in various ways. The chosen approach differs in dependency of the intended use of the structured product data [13]. For the generation of the initial product structure in the begin of product life the two major rivaling perspectives in industrial practice are those of engineering design on the one hand and manufacturing on the other hand. Whereas designers prefer functional oriented structures as this complies with their mindset of thinking about products, manufacturing favors a structure oriented on the production process. Other stakeholders in later lifecycle phases – in particular MRO and other services – have differing requirements on product structures. This results in many cases in the use of different product structures for the same system throughout its lifecycle. Workload for creation, transformation, maintenance and linking of these product structures cumulates in a substantial share of the overall costs of product creation and service.

Setting up of product structures in PLM systems is a manual task if there is no interface to CAD system available or if 3D product models have been generated by a reverse engineering principle. Big companies have divisions for data generation or modeling, product structure management in PLM Systems and usage of data for reengineering. The structure manager has to code single part files following the company's specific naming convention. Therefore he has to set up a PLM structure template which includes main structure nodes meaning sub-assemblies and related parts. This template is custom made for a product and cannot easily be transformed to another product or a variant of a product. Then, he has to save CAD models in a proprietary file format with a specific name and ID according to the structure template. Afterwards he imports all CAD files into the PLM system and stores them as datasets. For visualization he has to create additional files such as JT files form the proprietary files either with the CAD tool or an extra tool to import and store it to the right data set. To sum up the whole process of structure managing is highly manual and error-prone because of no exiting error recognition system or functionality.

3. Method for automated structuring of product data

The developed method for automated generation of product structures is a two-step procedure:

1. Identification of spatial relations between parts
2. Hierarchical structuring of related parts.

The approaches to these steps are described in the following.

3.1. Step 1: Neighborhood analysis using contact graphs

Prior to the explanation of the applications it is important to understand the fundamentals of graphs and their characteristic in this particular case. A graph G is an abstract datatype which represents a structure. It consists of a finite set of vertices (or nodes) V and edges E. Additionally, it is