Journal of Manufacturing Systems 36 (2015) 95–108

Contents lists available at ScienceDirect

Journal of Manufacturing Systems

journal homepage: www.elsevier.com/locate/jmansys

Technical Paper

Assembly oriented control algorithm of collaborative disassembly and assembly operation in collaborative virtual maintenance process

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ARTICLE INFO

Article history:
Received 23 August 2014
Received in revised form 15 March 2015
Accepted 15 March 2015
Available online 18 May 2015

Keywords:
Assembly oriented
Control algorithm
Collaborative disassembly/assembly operation
Collaborative virtual maintenance
Object information template
Information description

ABSTRACT

Maintenance data and information processing is an essential and important problem in collaborative virtual maintenance of complex equipments. Significant research has been done in this paper to provide an efficient approach to performing the data and information processing of collaborative virtual disassembly and assembly operations. Assembly oriented mathematical model of collaborative virtual maintenance operation process is presented with the behavior representation and information description of each component in an assembly based on single object oriented modeling of collaborative maintenance operation as well as assembly oriented modeling of disassembly and assembly operations. Assembly oriented control algorithms of disassembly and assembly operations in collaborative virtual maintenance process are also designed to perform the required data and information processing. With the object information template based on Extensible Markup Language, proposed mathematical models and control algorithms are utilized in a technical experiment system with high reliability and efficiency. Experimental implementation has been done to find appropriate and efficient mathematical models and control algorithms can support effectively the data and information processing of collaborative virtual disassembly and assembly operations of complex products. Methodologies developed in this paper extend the previous work on mathematical modeling and information processing complexity, and improve the reliability and efficiency of required data and information processing in collaborative virtual maintenance process.

1. Introduction

Collaborative virtual maintenance (CVM) that developed mainly based on virtual maintenance (VM) [1,2] and computer supported cooperative work (CSCW) [3–6] provides an appropriate and efficient approach to collaborative maintenance training of the large-scale and complex equipment. The studies on key techniques of CVM and the developments of training systems are gradually concerned by many researchers [7–13]. However, the research fields and contents involved in CVM are quite extensive and complicated, and the related supporting technologies and the application developments need to be studied further. As CVM mainly focuses on the requirements of collaborative maintenance operation training of multi operators in the different workstations of complex equipments [8,10], one of the essential parts is the efficient mathematical model and control algorithm of collaborative maintenance operation process (CMOP) including disassembling, replacing/repairing, assembling of the separated parts and components of an integrated assembly. However, there still are some deficiencies in the existing researches:

1 Present VM mostly focuses on the disassembly and assembly process of an assembly as well as the corresponding analysis and simulation [14–18]. However, the collaborative relationships of required maintenance operators and resources are considered scarcely when performing the disassembly or assembly operations of the parts and components in sequence. So the relevant mathematical models and control algorithms in VM can not represent all the required factors of the real maintenance operation process of complex equipment, which restricts the maintenance operation planning, maintenance training and design, maintainability analysis and forth.
2 Although the collaborative relationships of required maintenance factors such as maintenance objects, operators, resources and operation information have been taken into consideration in the mathematical modeling of CVM operation process, the supporting techniques and effective methods for the operation process of CVM need further studies. Especially the efficient control algorithm and management method of collaborative virtual disassembly and assembly processes of the complex assemblies.

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http://dx.doi.org/10.1016/j.jmsy.2015.03.009
0278-6125/

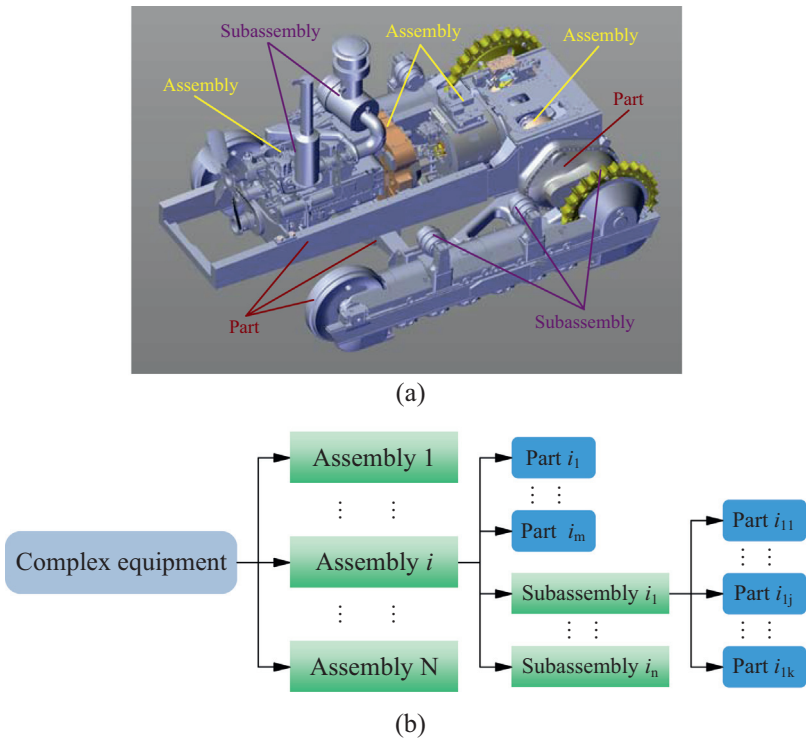

Fig. 1. Hierarchical structure of complex equipment.

3 The collaborative maintenance operation model (CMOM) of single component proposed in [10] takes the synchronous collaboration (SC) and asynchronous collaboration (AC) modes of required operators and resources into consideration, but there are many separated parts and components in an assembly. Therefore, for the efficient control and management methods of CVM operation process of an assembly, the entire disassembly and assembly sequences of all separated parts and components as well as the relevant operation information need to be considered equally.

Bearing the above observations in mind, the assembly oriented modeling, control algorithm and management method of disassembly and assembly operation processes in CVM are studied further based on CMOM of single component. For the development of practical application system, maintenance information processing is the most important link in utilizing the underlying models (logical, mathematical or physical etc.) to simulate and represent the actual maintenance process. In order to actualize the control and management of disassembly and assembly operation processes in CVM, the relevant mathematical models and information processing algorithms of CMOP should be analyzed, studied and established by taking the various factors of real maintenance operation process and their interrelated collaboration into full consideration. As CMOP is the organized combination of disassembly and assembly operations of the parts and components, the CMOP of single component as well as the disassembly and assembly processes of multi separated components of the assembly should be considered and analyzed in the mathematical modeling and control algorithms of CVM operation process.

The objective of this paper is to develop appropriate and efficient mathematical models and control algorithms for the data and information processing of collaborative virtual disassembly and assembly operations of complex assembles. The rest of this paper is organized as follows. Single object oriented modeling of collaborative maintenance operation, assembly oriented modeling of disassembly and assembly operation as well as assembly oriented modeling of CVM operation process are analyzed and described in Section 2. Based on the assembly oriented operation process model of CVM, in order to perform the data and information processing of the assemblies, the control algorithms of the disassembly and assembly operation process in CVM are proposed in Section 3. The implementation details of the proposed models and algorithms in CVM operation process are discussed and presented in Section 4. Finally, the study is ended with several concluding remarks of our research work in Section 5.

2. Assembly oriented mathematical model of CVM operation process

There are large numbers of assemblies in the complex equipment, and each of them is usually composed of parts and subassemblies. For each of the subassemblies that cannot or need not be disassembled, it is commonly considered as a separated component of the assembly. The subassemblies that need be disassembled also include parts and components, so the basic construct units of an assembly are the separated parts or components. The composition of complex equipment is shown in Fig. 1(a), and its hierarchical structure can be described as in Fig. 1(b). According to the construction features of complex equipment, the hierarchical structure besides the collaborative operations of multi operators should be taken into consideration in the maintenance process of an assembly. After each subassembly has been disassembled from the parent assembly, the further operation processes of them need be performed respectively according to the requirements of collaborative maintenance training. So the assembly oriented mathematical modeling of CVM operation process needs be analyzed and performed from parts to assemblies.

2.1. Single object oriented modeling of collaborative maintenance operation

During the CMOP, the collaborative relationship of multi operators for a specific maintenance object (a single part or a