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Optimal disassembly scheduling with a genetic algorithm

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Abstract

The growing amount of waste has caused severe environmental problems such as the shortage of landfill space and the high costs of waste disposal. Therefore, it is required to reuse and recycle the end-of-life products effectively from the viewpoint of economic efficiency. In this paper, we propose a disassembly scheduling method which uses a genetic algorithm to generate an optimal disassembly schedule including both the disassembly processes of multiple products and the post processes for reusing and recycling the disassembled parts for the minimization of the whole disassembly and post process times.

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Keywords: Optimal Disassembly Sequence; Ganetic Algorithm; End-of-Life; Remanufacturing; Reusing; Recycling

1. Introduction

In recent years, there is a growing interest in environmental issues such as air pollution, global warming, resource depletion and waste disposal. The growing amount of waste has caused severe problems about the shortage of landfill space and the high costs of waste disposal. They are serious problems to reduce the amount of waste for the creation of a sustainable society. Most of manufacturing companies require reusing and recycling the end-of-life (EOL) products for waste reduction and material circulation. Many manufacturing companies have been working on facilitation of reusing and recycling products in design phase of the products. Then, a lot of products are designed for easily disassembly to reuse and recycle. Some companies have also been constructing a closed loop system of collecting used products for reusing and recycling from the market. However, the closed loop system is not fully functioning in the actual marketing environment due to economic reasons. Therefore, it is necessary to carry out disassembly processes efficiently from the view point of economic efficiency in consideration of disassembly process times in the reusing and recycling of products. The consideration of efficiency of disassembly processes leads to enhance the processing capability of reusing and recycling. The cost to reuse and recycle an EOL product can be decreased by a large amount of reusing and recycling EOL products in a short time. Therefore, it is necessary to make an optimal schedule for reusing and recycling EOL products.

Existing researches have proposed disassembly scheduling methods to find a suitable disassembly schedule for a single product. These methods are considered neither the disassembly processes of multiple products nor the post processes such as cleaning and inspecting of the parts disassembled from the products for reusing and recycling. These methods cannot make an optimal disassembly schedule in consideration of the reusing process including the disassembly processes of multiple products and the post processes of the disassembly processes. Therefore, we propose a scheduling method of generating an optimal disassembly schedule in consideration of both the disassembly processes of multiple products and the post processes of the disassembly processes by using a genetic algorithm (GA).

This paper provides a new gene model to efficiently generate an optimal disassembly schedule through the evolutionary process of genes without infeasible chromosome. A prototype of scheduling system is developed in order to verify the effectiveness of the proposed method. We carry out a large number of computational experiments though the developed scheduling system.

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2. Literature review

Various researchers have proposed disassembly scheduling methods. Seo et al. [1] proposed the GA approach to search optimal disassembly sequences of a product considering both economic and environmental aspects. Their study considered the precedence relationships of disassembly operations as the target of refrigerator door modules. However, this method leads to infeasible strings in a gene model during the crossover and the mutation operations. The genes with the infeasible strings should be eliminated during latter generations. The infeasible strings weaken the searching ability of GA. Kongar et al. [2] proposed a method using a GA for efficiently retrieving parts which have been already determined to reuse or recycle from the EOL product. They employed the precedence preservative crossover (PPX) technique as the crossover method for disassembly problem. The methodology preserves the precedence relationship of parts during the crossover function of a GA. Shimizu et al. [3] developed a prototype system using a genetic programming (GP) for supporting a strategy to retrieve desired parts or subassemblies from an EOL product efficiently. These existing studies have the purpose of optimizing the disassembly process of a single product. The proposed methods are considered neither the disassembly processes of multiple products nor the post processes of the disassembly processes.

We have developed a scheduling method considering both the disassembly processes of multiple products and the post processes for reusing and recycling the disassembled parts in reference to our previous scheduling method for machining and assembly operations [4]. Fig. 1 shows an example of an individual for disassembling sequence used in the method. The job $J_{i,k}$ represents the k-th part of the product i. The disassembly $D_{i,h}$ means a final product or an intermediate product retrieved by the h-th disassembly operation in the product i. An individual for disassembling sequence used in the method is represented by job $J_{i,k}$ and disassembly $D_{i,h}$. However, this method also weakens the searching ability of a GA during the crossover and the mutation operations since the crossover and the mutation operations often generate lethal genes which represent infeasible schedules. Therefore, in this paper, we propose a new gene model that creates no lethal genes during the crossover and the mutation operation of a GA for generating an optimal disassembly schedule efficiently.

3. GA for optimal disassembly schedules

The gene model represents a whole schedule including both the disassembly processes of multiple products and the post processes of the disassembly processes for reusing and recycling the disassembled parts. In generating a whole schedule including both the disassembly processes and the post processes, we need to consider three kinds of information; they are the sequence of products loaded to the disassembly process, the disassembly sequence of each product for retrieving desirable parts from the EOL product, and the sequence of parts loaded to the post processes of the disassembly processes for reusing and recycling. The gene structure representing the whole schedule is developed in order to prevent creating lethal genes during the crossover and the mutation operations.

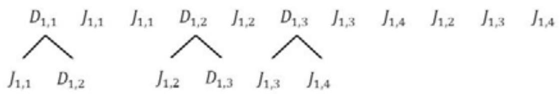

Fig.1 An individual for disassembling sequence.

3.1. Modeling for evolutionary algorithms

Three kinds of information are needed to create the whole schedule including both the disassembly processes and the post processes of the disassembly processes. They are the sequence of products loaded to the disassembly process, the disassembly sequence of each product for retrieving desirable parts from the EOL product, and the sequence of parts loaded to the post processes of the disassembly processes for reusing or recycling. These three kinds of information are represented by using four genes; they are the loading sequence of products, the disassembly procedure of a product, the sequence of removing parts, and the loading sequence of parts.

The information of the sequence of products loaded to the disassembly process is represented by using a gene, named as the loading sequence of products in this paper. The loading sequence of products shows the order of products whose disassembly operations are carried out. The individual representing the loading sequence of products is created by putting the product names in order of the starting times of disassembly operations.

The information of the disassembly sequence of each product for retrieving desirable parts from the EOL product is considered by using a chart of disassembly structure of a product. In considering a product with four parts as shown in Fig. 2 and Fig. 3, by way of example, a chart of disassembly structure of a product is shown in Fig. 7. A chart of disassembly structure of a product is represented by using two chromosomes.

The first chromosome as shown in Fig. 4, named as the disassembly procedure of a product in this paper, represents the disassembly way of a product for considering the structure of intermediate products retrieved on the way to disassemble the product. In the structure, the left intermediate product is disassembled prior to the right intermediate product. In case of the disassembly process to disassemble from an intermediate product to two intermediate products, the next disassembly process is to disassemble a left intermediate product in the disassembly structure. After that, a right intermediate product is disassembled. In Fig. 4, the number of disassembly procedure is written in each disassembly structure. The way of making this individual is shown in Fig. 5. For example, we show the way of making the individual of the left disassembly structure in Fig. 4. Each intermediate product is seemed as a node, we calculate the node number of each intermediate product. The individual is made by arranged the node number of intermediate products.