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A multi-objective algorithm for task scheduling and resource allocation in cloud-based disassembly

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ABSTRACT

Some manufacturers outsource their disassembly tasks to professional factories, each factory of them has specialized in its disassembly ability. Different disassembly facilities are usually combined to execute disassembly tasks. This study proposes the cloud-based disassembly that abstracts ability of the disassembly factory as the disassembly resource, the disassembly resource is then able to be allocated to execute disassembly tasks. Based on this concept, the cloud-based disassembly system is proposed, which provides the disassembly service according to the user requirement. The disassembly service is the execution plan for disassembly tasks, which is the result of scheduling disassembly tasks and allocating disassembly resources. To formally describe the disassembly service, this paper builds a mathematical model that considers the uncertainty nature of the disassembly process and precedence relationships of disassembly tasks. Two objectives including minimizing the expected total makespan and minimizing the expected total cost of the disassembly service are also discussed. The mathematical model is NP-complete, a multi-objective genetic algorithm based on non-dominated sorting genetic algorithm II is designed to address the problem. Computation results show that the proposed algorithm performs well, the algorithm generates a set of Pareto optimal solutions. The user can choose a preferred disassembly service among Pareto optimal solutions.

1. Introduction

In the past two decades, the development of information technologies created a booming market of electronic products. The amount of consumer electronic equipments kept on increasing, billions of computers and mobile phones have been designed and manufactured [1,2]. A large number of electronic devices are reaching the end of their service life, which is leading to the problem of Waste Electrical and Electronic Equipment (WEEE) treatment. Obsolete electronic devices contain hazardous materials, any improper disposal of them may seriously affect environment and harm to public health. To deal with these difficulties, Organization for Economic Co-operation and Development (OECD) took an imperative approach – Extended Producer Responsibility (EPR), which gives manufacturers greater responsibility for the reuse, recycling, and disposal of waste products [3]. Developing countries including China have been trying their best to establish recycling systems based on EPR [4].

However, some companies are incapable to recycle the complicated products because of lacking recycling technologies [5]. In China, for example, most enterprises outsource their waste management businesses to a single company [6]. These enterprises take the advantages of outsourcing which helps them to reduce costs and focus on their core businesses. Recycling of the waste product involves treating processes such as collection, inspection, testing and disassembling. The enterprises can outsource some of them according to their requirements [7].

Disassembly is the physical process of separating a product into its components or subassemblies, which can be classified as non-destructive, partially destructive and destructive [8]. Disassembly is an important step of recycling processes, hazardous substances and precious materials are usually extracted from products in this process [9]. Disassembly cells and disassembly lines are main facilities for executing disassembly tasks. The disassembly cell can flexibly adapt to different disassembly tasks. The disassembly line is extremely suitable for disassembling large products, the objective of which is to use the available disassembly resource efficiently [10]. Robot-based disassembly cell and disassembly line balancing (DLB) have been independently studied for many years [11,12]. In reality, different types of disassembly facilities execute tasks together. Take the disassembly of the mobile phone for example,

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removing the battery is manually carried out by the disassembly cell to achieve maximum flexibility, other parts can be directly disassembled by the disassembly line [13]. In this example, different disassembly facilities are integrated to a hybrid disassembly system.

Cloud manufacturing (CMfg), a new paradigm for scheduling, allocating and managing manufacturing resources, is receiving more and more attention. CMfg is regarded as the manufacturing version of cloud computing, it adopts concepts and technologies of cloud computing to achieve manufacturing-as-a-service. This means that distributed manufacturing resources are encapsulated to services. Searching, mapping and recommendation of manufacturing services are automatically executed in the CMfg platform [14]. CMfg has some distinct advantages, flexibility is one of them. CMfg adapts to mutable manufacturing environment by adjusting the manufacturing plan [15].

After learning concepts of CMfg, Wang and Wang [16] proposed a cloud-based WEEE remanufacturing system that integrates remanufacturing resources of different sectors. In order to meet the requirements of different users, the proposed system provides customized remanufacturing services. The further study indicates that cloud-based disassembly (CBD) is one of the advanced CMfg technologies for WEEE remanufacturing [17]. CBD is a novel concept for integrating disassembly resources and developing the hybrid disassembly system.

The CBD system (CBDS) is consisted of disassembly cells and disassembly lines. In the CBDS, disassembly resources belong to different facilities, disassembly tasks are executed collaboratively. So, flexibility is an important feature of the CBDS, which inherits advantages of CMfg. Studies of CBDS are different from previous studies, researches of the disassembly cell focus on designing disassembly robots [17], researches of the disassembly line focus on minimizing the number of disassembly workstations and improving the utilization ratio of workstations [18]. The CBD, on the other hand, concerns more about task scheduling and resource allocation (TSRA) of disassembly tasks and disassembly resources. The purpose of CBD is to provide optimal disassembly services that meet the requirements for disassembling products.

In conclusion, CBD is a brand new research field. To our best knowledge, this paper is the first one that fully depicts the concept of CBD. In CBDS, different disassembly devices are viewed as unified disassembly resources that can be allocated, disassembly tasks are scheduled and executed. The user submits the disassembly requirement which contains disassembly tasks, the CBDS then accepts the requirement and allocates disassembly resources according to the requirement. The disassembly service encapsulates the result of TSRA of disassembly tasks and disassembly resources, which also implies service details such as the disassembly makespan and the disassembly cost.

In this paper, disassembly service is formally described by a mathematical model. Minimizing expected total makespan (ETM) and minimizing expected total cost (ETC) of the disassembly service are two optimal objectives of the model, the proposed model is NP-complete. To obtain the optimal disassembly service by solving the problem, a multi-objective genetic algorithm (MOGA) based on non-dominated soring genetic algorithm-II (NSGA-II) is designed in this paper. This paper extends previous researches of the disassembly cell and the disassembly line, the goal of this study is to improve the flexibility of disassembly tasks and disassembly resources. The user of CBDS is able to obtain executable disassembly services according to requirements without realizing the specific process of TSRA.

The rest of this paper includes seven sections. Section 2 reviews the related studies of disassembly system and TSRA. The CBDS is introduced in Section 3. Based on Section 3, Section 4 builds a mathematical model for TSRA of disassembly tasks and disassembly resources. A MOGA based on NSGA-II is designed in Section 5, which solves the model built in Section 4. Section 6 presents simulation experiments of the proposed algorithm. Finally, Section 7 concludes the paper and proposes future works.

2. Literature review

In some circumstances, disassembly can be viewed as the reverse process of assembly. Theories of assembly such as assembly sequence planning and assembly line balancing have been directly applied to some studies of disassembly. However, assembly and disassembly have differences, one significant feature of the disassembly process is high uncertainty [19]. Güngör and Gupta [20] presented some failures of the disassembly line, such as e-leaving, self-skipping, skipping, disappearing and revisiting parts. Their work indicates the high uncertainty of the disassembly process, they also proposed some methods to deal with the uncertainty. To improve the monetary throughput of the disassembly line, Altekin and Akkan [21] proposed a predictive-reactive approach based on mixed-integer-programming. Moreover, some papers analyze the disassembly line from profit perspective. Altekin et al. [22] defined the problem of profit-oriented partial DLB, a lower-bounding and upper-bounding scheme based on linear programming was proposed to solve the problem. Colledani and Battaïa [23] proposed a methodology to design disassembly lines under variability of the end-of-life product quality, the objective is to maximize the profit. Similarly, Bentaha et al. [24] presented a stochastic mixed binary program to maximize the profit of disassembly line under uncertainty of the task time.

DLB is a hot topic of disassembly studies. Objectives of these studies usually include minimizing the number of disassembly workstations and minimizing the total idle time of the disassembly process [18]. McGovern and Gupta [32] proved that the problem of DLB is ascribed to the class of NP-complete problems. NP-complete problems are known for the difficulty to get the best solution, heuristic algorithms such as genetic algorithm (GA), ant colony optimization (ACO) and particle swarm optimization (PSO) are usually used to obtain the near-optimal solution of the given problem. To solve the problem of DLB, McGovern and Gupta [33] presented a GA for obtaining near-optimal solutions. Aydemir-Karadag and Turkbey [34] designed a GA that optimizes the DLB and design costs simultaneously. Kalayci et al. [35] proposed a hybrid discrete artificial bee colony algorithm to solve multi-objective fuzzy DLB problem. Kalayci and Gupta [36] presented a DLB problem that is sequence-dependent, the assignment of disassembly tasks should satisfy disassembly precedence constraints. A PSO algorithm with a neighborhood-based mutation operator was proposed to solve the problem. In general, previous studies show that heuristic algorithms perform well in solving DLB problems.

In addition to DLB problems, Andrés et al. [38] proposed a two-phase approach to reduce disassembly costs, the approach optimizes disassembly sequence and the configuration of disassembly cells. To minimize inventory level of products, Prakash et al. [39] designed a constraint-based simulated annealing algorithm to determine the sequence and disassembly schedule. Kizilkaya and Gupta [12] utilized Kanban system to control the material flow in disassembly cells. The robot-based disassembly cell was also discussed in some studies [11], but the TSRA of disassembly cells has not attracted much attention. Table 1 is the summary of literatures of disassembly systems, it concludes types of disassembly systems, optimization objectives and solver methods.

TSRA of job-shop, or so called flexible manufacturing system (FMS), is a hot research topic. To solve TSRA problems of the job-shop, heuristic algorithms including GA and ACO are applied to generate the optimal schedule [40–43]. Masin et al. [44] proposed