Selective Disassembly Research

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Abstract: This article transforms the disassembly graph model into a disassembly matrix model, and plans the path of selective disassembly by solving the matrix model.By conducting selective disassembly research on key components, a disassembly path is planned. When disassembling key parts, the goal is clear and unnecessary disassembly steps are omitted, greatly shortening the disassembly time and improving disassembly efficiency.This article presents the results of this study through a case study, proving that the results can transform complex component connection diagrams into matrices, and then plan the disassembly path of key components.

Keywords: selective disassembly, disassembly information modeling, disassembly path planning

Introduction

The widespread application of industrial products has dramatically improved human living standards and promoted social progress. At the same time, it also generates a large amount of industrial waste, posing a threat to the ecological environment and human health. According to previous research, 70% of environmental pollution is caused by debris from manufacturing enterprises. Disassembly is a prerequisite for solving the problem of remanufacturing waste products.Many researchers have solved various disassembly problems, such as disassembly design, disassembly methods, disassembly line balancing , DSP, and batch disassembly issues .

1. Selective disassembly sequence planning

Disassembly sequence planning determines the disassembly sequence of key components under specific objectives, such as minimizing disassembly time and cost. Research has shown that disassembly sequence planning is an NP-complete problem. The disassembly sequence planning consists of three steps: selecting disassembly modes, modeling disassembly constraints, and determining optimization methods, as shown in Figure 1.

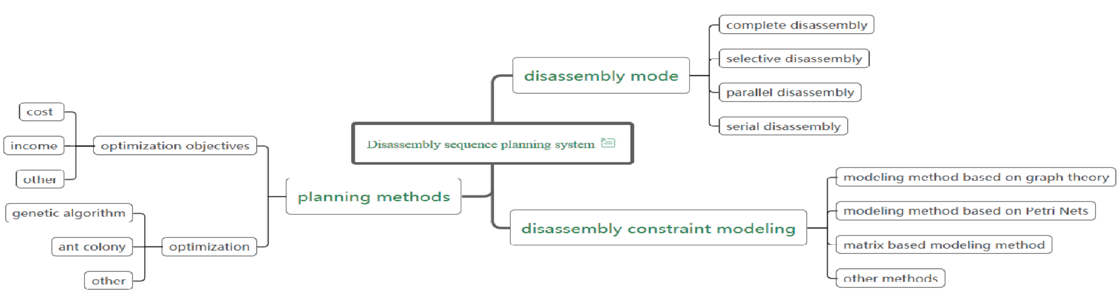

Fig1 Disassembly sequence planning

The disassembly model is a method of extracting the part information of the product to be disassembled, including connection and constraint information, integrating it into standard format graphics, matrices, tables, or sets, and then generating feasible disassembly sequences based on established rules. Establishing a disassembly model is the foundation for conducting disassembly research and provides valuable information for related research. There are various methods for establishing disassembly models, including graph theory-based, Petri net-based, object-oriented, etc. Among them, graph theory-based methods are commonly used. In this paper, the Mixed graph representation is used to build the disassembly model of the product, where the components are represented by the vertices of the Mixed graph, and the connection relationship between the features is defined by the edges of the Mixed graph.

2. Basic concepts and properties of graphs

Graphs are powerful tools for describing the relationships between discrete objects in the real world. In Set theory, a graph represents Binary relation, called a relational graph. The same method can also be used to describe other problems. When considering travel issues, points can be used to describe cities, and lines can be used to describe routes, railways, or highways between cities; When studying computer networks, we can use points to represent computer terminals and lines to represent information channels between computers; When looking the chemical structure of substances, points can be used to describe chemical elements, and bars can be used to represent Chemical bond between elements. In this representation, the position of points and the length and shape of lines are irrelevant. What matters is whether there is a connecting line between the two points, which can be considered an essential property of graphs in graph theory.

2.1 Concept of Figures

An undirected graph G refers to a binary group □V,E□, where V is a non-empty set of nodes, and E is a set of edges, with each edge always associated with two nodes.

If edge ei is associated with unordered node pairs (vi, vj), the edge is called an undirected edge. In a directed edge ei, if the two node-ordered pairs associated with ei are<vi, vj>, then vi is called the starting node of ei, and vj is the ending node of ei.

If every edge of graph G is an undirected edge, it is called an undirected graph; If every edge in graph G is a directed edge, it is called a directed graph; If there are both directed and undirected edges in a graph, it is called a mixed graph, represented by G=<V, E, DE>.

2.2 Matrix representation of graphs

If G=<V, E>is a simple graph with n nodes V={v1, v2,..., vn}, then define an n as follows × Matrix A of n=(aij) n × n. Among them:

$$aij=\begin{cases}0 & \text{i and j are not adjacent}\\ 1 & \text{i and j are adjacent}\end{cases}, (1)$$

From this definition, we can see that the matrix element defined by this method is either 0 or 1, so this matrix is called the Adjacency matrix of graph G.

3. Establishment of disassembly Mixed graph model

In Fig2, vertices 1 to 2 are undirected edges, indicating a contact constraint relationship between parts 1 and 2. DE is a directed edge, representing a non-contact constraint relationship between parts and a priority relationship. As shown in Figure 2, vertex 4 to vertex 1 are required edges, indicating that part 4 is disassembled before part 1.

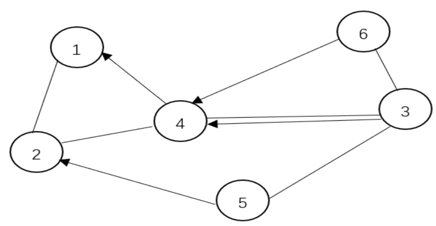

Fig 2 Disassembly Mixed graph

The undirected and directed edges in the disassembly Mixed graph can be represented by the connection matrix and the direction priority matrix,

G={V, E, DE} can be decomposed into G1={V, E} and G2={V, DE}. Assumption

G={V, E, DE} is a dismounted Mixed graph with N vertices, then G can be decomposed into two N-dimensional dismounted Mixed graph matrices G1 and G2:

$$G_1 = \{ lc_{ij} \} = \begin{bmatrix} lc_{0,0} & lc_{0,1} & \cdots & lc_{0,n-1} \\ lc_{1,0} & lc_{1,1} & \cdots & lc_{1,n-1} \\ \vdots & \vdots & \vdots & \vdots \\ lc_{n-1,0} & lc_{n-1,1} & \cdots & lc_{n-1,n-1} \end{bmatrix},$$

其中 $lc_{ij} = \begin{cases} 0 & \text{There is no connection between i and j} \\ 1 & \text{There is a connection between i and j} \end{cases}$, i=j时 lc_{ij}=0, lc_{ji}=0, (2)

$$G_1 = \{ pc_{ij} \} = \begin{bmatrix} pc_{0,0} & pc_{0,1} & \cdots & pc_{0,n-1} \\ pc_{1,0} & pc_{1,1} & \cdots & pc_{1,n-1} \\ \vdots & \vdots & \vdots & \vdots \\ pc_{n-1,0} & pc_{n-1,1} & \cdots & pc_{n-1,n-1} \end{bmatrix},$$

其中 $pc_{ij} = \begin{cases} 0 & \text{There is no priority disassembly relationship between i and j} \\ 1 & \text{j must be disassembled before i} \end{cases}$, i=j 时 pc_{ij}=0, pc_{ji}=0, (3)

The connection matrix in Figure 2 is:

$$G1=\begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}$$

The priority matrix of Figure 2 is:

$$G2=\begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

4. Selective disassembly sequence generation

The process of specifying a specific component (single target) or a group (multiple targets) throughout the entire product lifecycle to achieve low maintenance costs and high recycling rates, and determining the disassembly sequence that includes that group of components, is called selective disassembly. This article only discusses the selective disassembly sequence of designated key parts. To disassemble key parts, selecting a part from the detachable parts for disassembly is necessary until a feasible disassembly sequence is generated. A detachable part refers to a part that is not subject to priority constraints from other parts, i.e., satisfies equation (4), and only has a contact constraint relationship with one of the other parts, i.e., satisfies equation (5).

$$\sum_{j=0}^{N-1} Pc_{ij} = 0 \quad (4)$$

$$\sum_{j=0}^{N-1} lc_{ij} = 1 \quad (5)$$

The selective disassembly of key parts is aimed at dismantling the key parts. From the perspective of geometric constraints in disassembly, the disassembly of key parts refers to the disassembly of parts that have contact or priority relationships with the key parts until the key parts are dismantled. The resulting sequence is a selective disassembly sequence.

As shown in Fig2, assuming the target disassembled part is 4, first determine the parts with contact and non-contact priority relationships with part 4, and place them in List C so that C={2, 3}. According to equations (4) and (5), generate a search space b (x)={} for detachable parts in C. If a is empty, determine whether the parts with contact and non-contact priority relationship with 2 and 3 are placed in C, so that C={1, 2,5, 3, 6,}, and b (x)={5, 6}. Select part 6 from b (x) as the disassembled part and place it in S so that S={6}. Generate b (x)={5} from C={1,2,3,5}, select part 5 as the disassembly part at this time, so that S={6,5}. Make judgments in sequence until the target part 4 can be disassembled. The judgment process is shown in Table 1. From Table 1, a selective disassembly sequence S={6, 5, 3, 4} can be obtained. The disassembly process is shown in Table 1.

Table1 Fig2 Selective disassembly process with target part 4

TX	C	b(x)	S
4	2,3		
	1,2,3,5,6	5,6	6
	1,2,3,5	5	6,5
	1,2,3	3	6,5,3
	1,2	4	6,5,3,4

5.Discussion

This article presents the problem of component disassembly by drawing a graphical model and transforming it into a component contact matrix and a component priority disassembly matrix. The matrix is solved through algorithms and finally demonstrated through a case study. The research in this article provides further explanations on the methods and steps of selective disassembly, laying the foundation for future research.

6.Conclusion

The autonomous and selective disassembly planning of key components requires machines to understand the component structure in three-dimensional space. A key step is to create machine-readable mathematical representations (or models) of contact and non-contact priority relationships based on the graph model. Another Committed step is to develop appropriate algorithms to solve the model to obtain feasible sequences. This article introduces a graph model to describe the information on product component selection and disassembly and uses the graph model to perform geometric reasoning on the solution space of key component disassembly sequences. The algorithm flowchart is provided, and an example is used to illustrate.The Mixed graph model of product disassembly is the basis of selective disassembly planning, which contains the information required for selective disassembly. The machine-readable mathematical representation (or model) of the contact relationship and non-contact priority relationship of parts is a constraint condition for solving problems. In the model-solving process, this article provides algorithm steps, but for complex products, a computer is still needed to solve them. The next step will be to study the application of algorithms for solving disassembly sequences of key parts in complex products.

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