Selective disassembly planning for the end-of-life product

Procedia CIRP (2017)

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Production and Logistics Information Laboratory
1. Introduction
Disassembly

- An essential operation in product recycling
  - To collect reusable components or valuable materials

- Disassembly process
  - Complete disassembly (recycling)
  - Incomplete disassembly (maintenance and remanufacturing)
    - Selective disassembly: disassembly of selected components in a product

- Destructive disassembly vs Non-destructive disassembly
Introduction

- **Problem definition**
  - Selective disassembly sequencing problem

- **Objectives**
  - Minimize total disassembly time

- **Decision variables**
  - Disassembly sequence

- **Constraints**
  - Precedence relationships

- **Proposed method**
  - Destructive disassembly method
2. UTD problem
UTD problem

- UTD (unable to disassembly) problems in the non-destructive disassembly
  - Constraint directed graph
    - Node: component
    - Arc: precedence

```
Target component
```
```
Ideal shortest disassembly sequence
\[ \rightarrow 8-6-5-1 \]
```
```
Longer disassembly path
\[ \rightarrow 2-7-3-5-1 \]
```

```
C4 and C6: riveting connection
```

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Introduction
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Introduction
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### UTD problem

- **UDT (unable to disassembly) problems in the non-destructive disassembly**
  - Destructive disassembly method
    1) **Draw** the graph to show connections of the product from design;
    2) **Represent** the product with the multi-level constraint matrix and fastener-component matrix;
    3) **Generate** feasible disassembly sequences considering both operations;
    4) **Evaluate** solutions for non-destructive and destructive methods using established criteria;
    5) **Select** the optimal disassembly sequence.
3. Disassembly sequence planning
Disassembly sequence planning

- **Product presentation and component constrains**
  - **Constraints of product disassembly**
    - Fastener constrain (F)
      - ✓ Commonly used in products (non-destructive)
      - ✓ Ex) bolts and screws
    - Destructive constrain (D)
      - ✓ Only be removed in a destructive way
      - ✓ Ex) gluing, welding and riveting etc.

<table>
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<th>Disassembly type</th>
<th>Constraint(F)</th>
<th>Constraint(B)</th>
<th>Constraint(M)</th>
<th>Constraint(D)</th>
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<td>Screwdriver Wrench</td>
<td>Pliers</td>
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<td>8-18s</td>
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<td>Tool</td>
<td>Electrical drill</td>
<td>Hammer Saws</td>
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Disassembly sequence planning

- **Product presentation and component constraints**
  - Multi-level constraint matrices
    - Tree structure: based on the BOM
    - Between one component and other components along ±X, ±Y, ±Z directions in Cartesian Coordinates of a product model
    - Assembly: $A= \{A_1, A_2, \ldots, A_n\}$ with $n$ components

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- Fastener-component matrix
  - To represent constraints to components from fasteners
**Disassembly sequence planning**

- **DSP process**
  1. Determine a target component;
  2. Search for the lowest subassembly which contains the target component;
  3. Generate all feasible disassembly sequences using the multi-level constraint matrices and fastener-component matrix;
  4. Compare feasible sequences using predefined criteria, such as the disassembly time;
  5. Select the optimal disassembly sequence.
4. Case study
Case study

- **Simplified mechanical arm**
  - 12 components (1-12), 11 fasteners (23-33), target component 8
Case study

- **Simplified mechanical arm**
  - Graph representation of fasteners in the mechanical arm

![Graph representation of fasteners in the mechanical arm](image)

Destructive disassembly
### Case study

- **Simplified mechanical arm**
  - Constraint matrices of the product and two first-level subassemblies

![Constraint matrices](image)

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Case study

- **Simplified mechanical arm**
  - Subassembly 2 contains the target component 8.
  - Parts (6, 7, 8, 9, 10, 11, 12)
  - Ex) sequence 6-7-11-8-9-10-12 → 6-7-11-8
  - Optimal disassembly sequence: FS2 - 21 - 22 - 7 - 8
  - Optimal disassembly time: \(18 + 2(20) + 20 + 15 + 8 = 81\) s

\[ ? + 25 + 25 + 15 + 8 \]
5. Conclusions
Conclusions

- Overview
  - Selective disassembly sequence planning
  - Multi-level matrices and fastener-component matrix
  - Destructive method
  - Case study
Thank You!

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