Disassembly sequence structure graphs: An optimal approach for multiple-target selective disassembly sequence planning

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1. Introduction
### Disassembly planning

- Modern green products must meet economic, environmental and social constraints
  - Easy to disassemble
- Product life cycle
  - Selectively disassembled to repair or replace parts
  - End of life: completely, partially or selectively disassembled to recover, reuse or recycle parts and materials
  - An important part of the product design process.

- The goal of this study
  - To improve solution quality, minimize model complexity and reduce searching time
- Two major steps
  - Creating a disassembly model and generating disassembly sequences
2. Disassembly model
Disassembly model

- **Disassembly graph model**
  - Five matrices
    - Contact constraint matrix for components (CC)
    - Contact constraint matrix for fasteners (CF)
    - Motion constraint matrix for components (MC)
    - Motion constraint matrix for fasteners (MF)
    - Projection matrix for components (PC)
  - Components: the elements providing functions in a product
  - Fasteners: the elements connecting components together
  - Parts: either components or fasteners
Disassembly model

- **Disassembly graph model**
  
  - Contact constraint matrix for components (CC)
    
    ✓ Contact constraints for each component
    
    ✓ Contact a component and fasteners that connect the component to other components
  
  - Contact constraint matrix for fasteners (CF)
    
    ✓ Contact constraints for each fastener: ex) CF₁=3 and CF₇=1
Disassembly graph model

- Motion constraint matrix for components (MC)
  - Motion constraints for each component
  - 'first-level parts', parts that intersect with a part's projection in any given direction

\[
MC = \begin{bmatrix}
MC_1 & +x & -x & +y & -y \\
MC_2 & f_1.f_8.4 & f_1.f_8 & 0 & 6 \\
MC_3 & f_1.f_3.f_{10}.4,7 & f_1.f_3 & f_2 & f_2 \\
MC_4 & f_3.f_4.f_5 & f_3.f_4.f_5 & 6.8 & 0 \\
MC_5 & f_5 & f_5,1,2,6,7,9 & f_6.f_7 & f_6.f_7 \\
MC_6 & f_8 & f_8 & f_7 & f_7.f_9,8 \\
MC_7 & f_4,4,9 & f_4 & f_2.f_{10},1 & f_2.f_{10},3 \\
MC_8 & f_4.f_8,4 & f_4.f_8,2 & 8 & 0 \\
MC_9 & f_9 & f_9 & f_6.f_{10},5 & f_6.f_{10},3,7 \\
\end{bmatrix}
\]

- Motion constraint matrix for fasteners (MF)
  - Motion constraints for each fastener: ex) \(MF_9=[0050]\) and \(MF_{10}=[0200]\)
Disassembly model

- **Disassembly graph model**
  - Projection matrix for components (PC)
    - Counts blocking components for each component
    - The number of components, at all levels, that block a component, in the given direction

\[
PC = \begin{bmatrix}
PC_1 \\
PC_2 \\
PC_3 \\
PC_4 \\
PC_5 \\
PC_6 \\
PC_7 \\
PC_8 \\
PC_9 \\
\end{bmatrix} = \begin{bmatrix}
1 & 0 & 1 & 4 \\
5 & 0 & 1 & 1 \\
0 & 0 & 8 & 0 \\
0 & 7 & 0 & 1 \\
1 & 0 & 0 & 6 \\
3 & 1 & 2 & 2 \\
1 & 1 & 5 & 1 \\
1 & 2 & 1 & 3 \\
1 & 2 & 2 & 2 \\
\end{bmatrix}
\]
3. DSSG model
Disassembly sequence structure graph (DSSG) model

- An inverted tree
  - Root nodes: target components
  - Leaf nodes: parts that constrain the target components
Disassembly sequence structure graph (DSSG) model

- An approach for creating a single-target DSSG
  - Expert rules
    - PC matrix
    - One disassembly direction
    - Two single-target DSSGs
    - Direction with the least number of obstacles (best direction)

Single-target DSSG for target component 7 (-x and -y direction)
Disassembly sequence structure graph (DSSG) model

- An approach for creating a multiple-target DSSG
  - Merges single-target DSSGs by merging identical nodes within the DSSGs
### Methods for searching DSSGs

- **Rules**
  - The approach removes leaf nodes in reverse order
- **Genetic algorithm**
  - Initial population: by randomly selecting parts from a DSSG
  - $S_1 = (f_4, f_7, f_8, 5, 9, 7, f_5, f_9, 4, f_6) \rightarrow S_2 = (f_6, f_7, f_8, 5, f_5, 4, f_9, 7, 9)$
  - Fitness function: $F_t = 1/(1 + R)$, $R=$ (reorientations, in degrees/90)
  - Genetic operators: to randomly modify the best solution
4. Case study
Case study

- **Drive assembly**
  - 19-parts and target component 3 and 6
  - disassembly sequence: $S_1 = (f_7, f_8, f_3, f_4, 5, 2, f_9, f_1, f_2, 4, 3, f_5, f_6, 6)$, with $R = 3$

Multiple-target DSSG for components 3 and 6
Example 3 (gear reducer assembly)

- 36-parts and target component 5, 7, 18 and 21

- Disassembly sequence: $S_4 = (f_1, f_2, f_3, 1, 2, 3, 4, 5, 6, 7, f_8, f_9, 23, 22, 21, 20, 15, 16, 17, 18)$, with $R = 1$
5. Conclusions
Conclusions

- Overview
  - Multiple-target selective disassembly sequence planning
  - Disassembly sequence structure graph (DSSG) model
  - Case study (two examples)
  - Eight new design rules
Thank You!