A SUBASSEMBLY IDENTIFICATION METHOD FOR OPTIMAL ASSEMBLY SEQUENCE GENERATION

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ABSTRACT

Stable sub assembly detection reduces the assembly efforts and time, in this paper detecting such subassemblies using part concatenation method considering different stability relations between pair of components is discussed. The stability due to mating surface features and involvement of physical connectors. The proposed method helps in finding possible parallel subassemblies during assembly sequence generation to achieve economized assembly process.

Key words: Subassembly detection, Assembly stability, Assembly sequence generation.


1. INTRODUCTION

Recent trends in Design For Assembly (DFA) encourages the engineers towards reducing the total number of parts to minimize assembly efforts, which greatly influence the part geometries. Finding a valid assembly sequence for the parts with altered topology is a challenging and complicated task. A valid sequence must exhibit two critical qualities namely feasibility and stability for its practical possibility [1-5]. Lots of research has been done on geometric feasibility testing through graphical methods and improved matrix representation methods [6-9]. Several researchers tried to extract interference free matrices from Computer Aided Design (CAD) based environment in order to minimize the time and efforts [10-14]. Bahubalendruni and Biswal made efforts to test geometric feasibility of assembling part using bounding box methods through CAD interfacing [15-22].

Stability is one essential criteria to be followed while generating assembly sequence, several researchers have not considered this criteria and few researchers assumed this criteria to minimize the computational time [11-13]. Smith proposed stability representation between parts considering hard and soft connections between pair of parts [11-12]. However these representation does not hold complete information due to narrow categorization. Bahubalendruni presented influence of considering and ignoring assembly stability criteria on optimal assembly sequence planning in terms of quality of resulted assembly sequence and

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computational time [6]. The literature reveal that no efforts are made using these stability matrix in finding out stable subassemblies in order to perform parallel assembly sequence generation. The proposed method is an attempt to detect stable subassemblies using combined stability matrix.

2. PREREQUISITES

In order to generate stable assembly subsets, liaison and stability matrices are used. Liaison matrix is a symmetric matrix created using binary codes (0,1), where “0” represents no surface contact between pair of parts indicated in row and column and whereas “1” represents significant surface contact. Combined stability matrix is a square matrix with three different types of possibilities namely partial stability, permanent stability due to part mating surfaces and usage of external connectors, which can be indicated with 1, 2 and 3 respectively. Liaison matrix and combined stability matrix for the 7-part product show in Figure 1 is listed below.

\[
\begin{bmatrix}
1 & 2 & 3 & 4 & 5 & 6 & 7 \\
1 & 0 & 1 & 0 & 1 & 1 & 1 \\
2 & 1 & 0 & 1 & 0 & 0 & 0 \\
3 & 0 & 1 & 0 & 0 & 0 & 0 \\
4 & 1 & 0 & 0 & 0 & 1 & 0 \\
5 & 1 & 0 & 0 & 1 & 0 & 0 \\
6 & 1 & 0 & 0 & 0 & 0 & 1 \\
7 & 1 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\]

\[
\begin{bmatrix}
1 & 2 & 3 & 4 & 5 & 6 & 7 \\
1 & 0 & 1 & 0 & 1 & 1 & 1 \\
2 & 1 & 0 & 1 & 0 & 0 & 0 \\
3 & 0 & 1 & 0 & 0 & 0 & 0 \\
4 & 1 & 0 & 0 & 0 & 1 & 0 \\
5 & 1 & 0 & 0 & 1 & 0 & 0 \\
6 & 1 & 0 & 0 & 0 & 0 & 1 \\
7 & 1 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\]

Figure 1 A 7-Part assembly

![Liaison Matrix for Product](image1.png)

Figure 1 Liaison Matrix for Product

![Stability Matrix for Product](image2.png)

Figure 2 Stability Matrix for Product

3. PARTIAL AND PERMANENT ASSEMBLY SUBSETS

An assembly subset is called as partial assembly subset, if at least one part in the subset is partially stable. These subsets further helpful in determining permanent assembly subset and sequential assembly sequence planning process. There exist two different possibilities of partial subset formulation as stated below.
Case 1
When appending part exhibits partial stability with respect to all parts in the existent assembly subset irrespective of the nature of the existent assembly subset. Let us consider part-6 to join an existent partial assembly subset (1-4), part-6 is offered only partial stability with respect to part-1 \((S(1,6)=1)\), which results in partial assembly subset \((1-4-6)\). While appending part-4 to assembly subset (1-2), though existent assembly subset is permanent stable, appending part-4 is offered only partial stability with respect to part-1 \((S(1,4)=1)\) results in partial assembly subset \((1-2-4)\).

Case 2
Even though appending part exhibits permanent stability with respect to all parts in the existent assembly subset, if the existent assembly subset is a partially stable the resulted nature will be partially stable. While appending part-2 to assembly subset \((1-4)\), though appending part-2 is offered permanent stability with respect to part-1 \((S(1,2)=3)\) results in partial assembly subset \((1-2-4)\) due to partial nature of existent assembly subset.

An assembly subset is called as permanent assembly subset, when all the parts in the assembly maintain its respective positions with respect to all mating parts irrespective of orientation. This can be achieved when all the parts in the sub assembly exhibit permanent stability. The permanent stable assembly subset can be formed at two different conditions.

Case 3
When appending part exhibits permanent stability with respect to any of the parts in the existent permanent stable assembly subset. Let us consider part-3 to join an existent permanent assembly subset \((1-2)\), part-3 is offered permanent stability with respect to part-2 \((S(2,3)=2)\), which results in permanent assembly subset \((1-2-3)\).

Case 4
If appending part exhibits permanent stability with respect to any of the parts in the existent partially stable assembly subset as long as the partially stable part motions are completely constrained due to the appending part. While appending part-5 to assembly subset \((1-4)\), though existent assembly subset is partially stable, the appending part bring stability to all the unstable parts and results in permanent stable assembly subset \((1-4-5)\).

Table 1 All possible instances of assembly subset generation

<table>
<thead>
<tr>
<th>Possibility</th>
<th>Existent assembly subset</th>
<th>Nature of the Existent assembly subset</th>
<th>Appending part</th>
<th>Type of stability of appending part</th>
<th>Resultant assembly subset</th>
<th>Nature of the Resultant assembly subset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>1-2</td>
<td>Permanent</td>
<td>4</td>
<td>(S(1,4)=1) Partial</td>
<td>1-2-4</td>
<td>Partial</td>
</tr>
<tr>
<td></td>
<td>1-4</td>
<td>Partial</td>
<td>6</td>
<td>(S(1,6)=1) Partial</td>
<td>1-4-6</td>
<td>Partial</td>
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<tr>
<td>Case 2</td>
<td>1-4</td>
<td>Partial</td>
<td>2</td>
<td>(S(1,2)=3) Permanent</td>
<td>1-4-2</td>
<td>Partial</td>
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<tr>
<td>Case 3</td>
<td>1-2</td>
<td>Permanent</td>
<td>3</td>
<td>(S(2,3)=2) Permanent</td>
<td>1-2-3</td>
<td>Permanent</td>
</tr>
<tr>
<td>Case 4</td>
<td>1-4</td>
<td>Partial</td>
<td>5</td>
<td>(S(1,5)=3) Permanent</td>
<td>1-4-5</td>
<td>Permanent</td>
</tr>
</tbody>
</table>
4. ASSEMBLY SEQUENCE GENERATION METHOD AND ITS IMPLEMENTATION

The proposed method generate assembly subsets by appending a nonexistent part/subassembly to an existent assembly subset when it qualify defined assembly predicate testing methods. The necessary data to perform assembly predicate testing can be extracted from a product using existing methods [1]. When appending part qualify stability; the method will check for all the possible instances described in section-3 and the resulted assembly sets will be stored under two different categories. Therese resulted subsets will be further used to generate next level assembly subsets till the number of parts in assembly subsets equal to total number parts in assembly subset equal to the part count of the chosen product. The proposed method is indicated through flow chart in Figure 2.

**Figure 2** An efficient method of assembly sequence generation through subassembly identification

During the assembly subset generation if there exist any similar assembly subset with altered sequence, the redundant subset will be identified and erased using assembly indexing method [8]. Assembly index values and assembly subset alternate possible variants for 2-part assembly subsets are shown in Table 1. The proposed method is implemented on product shown in Figure 1 and the resulted intermediate level permanent and partially stable assembly subsets are listed in table 1.
Table 1 Assembly subset generation at intermediate levels

<table>
<thead>
<tr>
<th></th>
<th>2-Part subsets</th>
<th>Alternate sets</th>
<th>Assembly Index</th>
<th>3-Part subsets</th>
<th>4-Part subsets</th>
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<td>assembly subsets</td>
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<td>1-2</td>
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<td>10001</td>
<td>1-2-5</td>
<td>1-(2-3)-7</td>
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<td>7-1</td>
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<td>1-2-4-5</td>
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5. CONCLUSIONS

A novel method to generate assembly sequence generation through subassembly detection is proposed and illustrated with an example. Detailed possibilities of stability during subassembly detection is well discussed by considering different possibilities of assembly stability instance between pair of parts. The method can be implemented for parallel and sequential assembly sequence planning.

REFERENCES


A Subassembly Identification Method for Optimal Assembly Sequence Generation


