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Research Article

Computer Aid to Obtain Assembly Cut-sets from 3D CAD Product

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Abstract

In the field of assembly sequence planning, the increase of part count in a product results in huge number of assembly sequences. The Liaison matrix/Liaison graph generated based on the connections between the assembly components eliminates non possible assembly sequences at the initial phase. There exists methods namely cut-set method to eliminate the non-possible assembly sequences. In this paper, a computer aided program to obtain liaison matrix and generation of assembly cut-sets from liaison matrix is briefly explained with flow charts and algorithms

Keywords: *Cut-Set method, Liaison Matrix, Assembly connections.*

1. Introduction

Optimized assembly sequence of a product always plays major role in manufacturing industry in terms of cost effectiveness by optimizing the overall usage of machine tools and fixturing. It also supports in reducing the lead time of the product and improving the final product quality as well. Most of the researchers worked on finding out the at least one feasible solution to assemble the product, and to find out the optimized assembly sequence from the feasible and stable assembly sequences with considerable approximations and assumptions. Finding feasible and stable assembly sequences from all set of possible assembly sequences involves three major phases.

Phase-1 involved in eliminating the non-possible assembly sequences based on the connections between parts from all set of assembly sequences. There exist methods to represent all set of assembly sequences, which are AND/OR graph and Directed Graph (Homem De Mello and Sanderson) methods. The elimination of non-possible assembly sequences is based on the contacts between parts in the assembly. As the number of parts increases in an assembly, the all set of assembly sequences also increases exponentially. Hence this phase involves lot of computational time in eliminating the non-possible assembly sequences. The Liaison matrix/Liaison graph (Bourjault) is the simplest one to establish the connections between the parts. By employing Cut-set method (Homem De Mello and Sanderson) on the Liaison graph, the elimination of non-feasible assembly sequences can be done.

Phase-2 involved in finding the feasible assembly sequences from the liaison based assembly sequences by querying for precedence order and Phase-3 involved in finding out the stable assembly sequences from the feasible assembly sequences. At later phases optimal stable and feasible assembly sequence will be obtained subjected to assembly cost or assembly time.

This paper is more focused on the Phase-1, CATIA-Computer Aided Three dimensional Interactive Applications software is used to create 3D product and VB-scripting is used to interface with CATIA and to obtain the liaison matrix.

2. Liaison Graph and Liaison matrix

2.1 Liaison Graph

Liaison graph is a graphical representation of contacts between the assembled parts of a product. Though this method is initialized by Bourjaul and later it is popularized by De Fazio and Whitney.

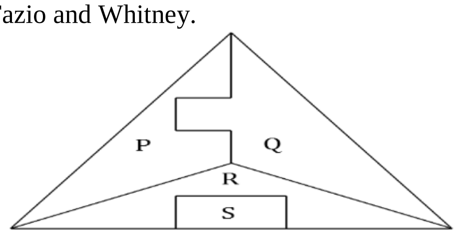

Fig.1 4-Part assembled Product

A liaison is a defined connection established between the components. The liaison diagram typically consist nodes and connectors connected to the nodes. The nodes represent the part, and the connectors from the node to other nodes represent the connections with the mating parts. These connections will be named to use further to

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establish precedence relations between the connections. A 4 part assembly shown in Fig.1 is used for experimentation purpose.

The liaisons diagram for 4 part assembly is represented in Fig.2. The parts are indicated in the nodes and the connections between the parts are indicated as connectors between the components.

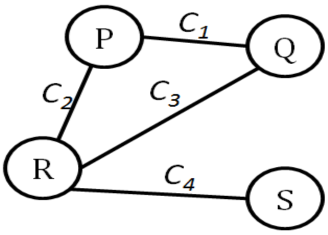

Fig.2 Liaison graph for 7 part assembly

2.2 Liaison Matrix

Dini proposed the matrix representation of liaisons between the components with binary codes 1, 0. An *nxn* matrix is required to represent the liaisons connections for a product assembled by "*n*" components. The diagonal elements of this matrix consist of null values, and the row of matrix represents the liaisons between one component and that with the other components in the assembly. The column of matrix represents the components connected by liaison relationships. The sub-matrices of *nxn* matrix represent the local liaison relationships in subassemblies.

3. Liaison Matrix extraction from CATIA

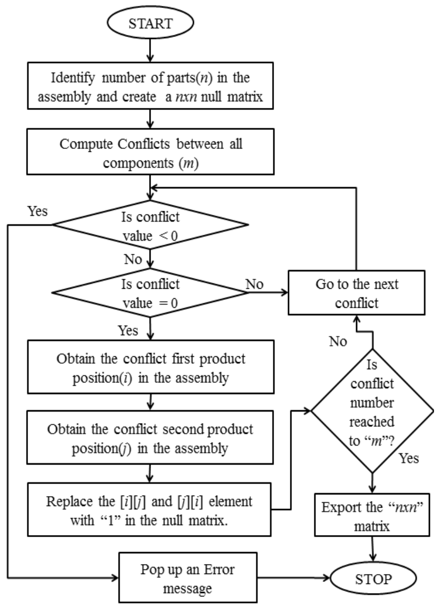

Fig.3 Liaison matrix extraction flowchart

There are three different types of conflicts exist between two components, first type of conflict is clearance indicated by a positive conflict value represents gap between the two components. Second type of conflict is clash indicated by a negative conflict value represents the depth interference value between two components. If a negative conflict value exits, it indicates that neither the parts are assembled properly nor the parts are created correctly. In such the liaison matrix extract code will pop-up an error and terminates the process. Third type of conflict is contact indicated by a null conflict value represents the contact between two or more faces of the components. Our interest is in capturing the pairs of parts which are in contact and placing in the matrix format. The liaison matrix extraction flowchart is shown in Fig.3. Liaison extraction code is demonstrated below.

1. Open an assembly in CATIA Assembly design
2. Obtain the number of parts in the Assembly "say n number of parts"
3. Create a null matrix of "*nxn*"
4. Compute the conflicts using "Clash computation type between all"
5. Obtain total number of conflicts "*m*"
6. For each conflict 1 to *m*

    Define the conflict type by conflict value

    If Conflict Value < 0

    Exit from the loop and pop up and error message

    If Conflict Value = 0

    Identify the conflict product.1 name in the parts list say i^{th} part

    Identify the conflict product.2 name in the parts list say j^{th} part

    Replace the null value with "1" for the [i][j] and [j][i] elements of null matrix

7. Export the matrix data to Ms-Excel.

By executing the macro, the liaison matrix for the assembly will be generated and exported to Ms-excel as shown in Fig.4.

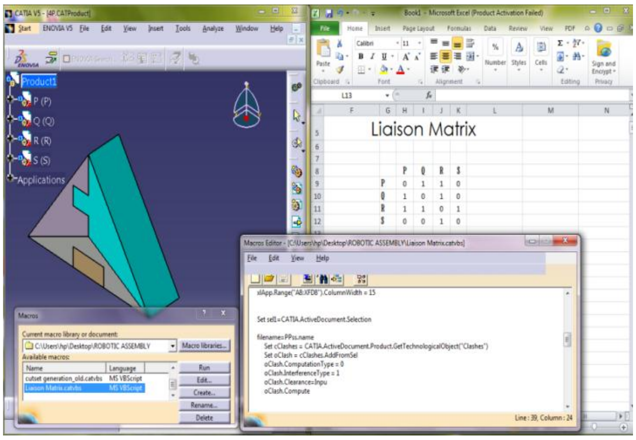

Fig.4 Macro interface with CATIA and Ms-Excel

Table.1 Liaison matrix for 4 part Assembly

	P	Q	R	S
P	0	1	1	0
Q	1	0	1	0
R	1	1	0	1
S	0	0	1	0

The non-diagonal unit values of the matrix represents that there is contact between the parts indicated in row & column.

4. Cut-set Method

In this phase implementation of Cut-set method on liaisons diagram to eliminate the non-possible assembly sequences is explained under certain assumptions. The first assumption is that, if a component can be disassembled from an assembled product at a phase without any destructive operation, the component can be assembled at that phase. So that if a sequence can be found to disassemble all the components from an assembled product, the reverse of the disassembly sequence is possible assembly sequence. The second assumption is at each phase of assembly or disassembly operation, there is no change in the geometry of the component. For the present case generation of parallel subassemblies is not considered.

4.1 Method of obtaining possible assembly sequences from Liaison matrix

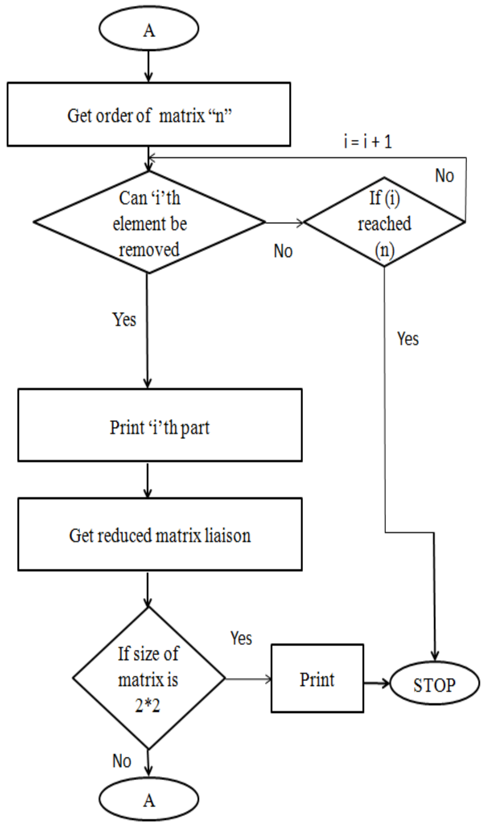

Fig.5 Cut-set Method

Based on the assumption, "the reverse procedure of disassembly sequence is assembly sequence of a product" if a component can be removed from an assembly at a stage without any destructive operation, the component can also be assembled at that stage. The possibility of removing a component at a phase can be checked through liaison matrix by eliminating the respective row and column of that element (ith part). In the sub-liaison matrix, if there exists a row (jth row) with null values, it represents that the jth component does not consist any connection with any of the other parts in the assembly. Else the sub-liaison matrix will be analyzed further. Typical cut-set method is represented in Fig.5.

The liaison matrix obtained from Fig.3 is input for this algorithm, the mechanism shown in Fig.5 generates the cut-sets based on the liaison matrix. A VB-script based code is described below to check whether "ith" part can be disassembled/not and to create a sub-liaison matrix.

```
If Not i=n then
  '**************can ith part be disassembled***************
  x=1
  for j=1 to n
   y=1;
   if j=i then  :        j=j+1      : End If
   sum[j]=0
   for k=1 to n
    if k==i then:  k=k+1: End If
     temp[x][y]=a[j][k] : y=y+1 '***Sub liaison matrix exporting
     sum[j]=sum[j]+a[j][k] '***computing the sum of Row elements
   Next
   x=x+1
  Next
  count=0;
  for var1=1 to n
    if var1==i then : var1+=1 : End If
    if sum[var1]==0 : count+=1: End If  '***At least one part does not have contact
  Next
  if count=0 Then : msgbox "The part can  be removed"    : End If
  if count>0 Then : msgbox "The part can  be removed"    : End If
End If
```

For the liaison matrix obtained in Table.1 to check that if "R" part can be removed or not. To check part "R" can be removed or not, the above mentioned mechanism works as mentioned in Fig.6.

a[4][4] i=3

	P	Q	R	S
P	0	1	1	0
Q	1	0	1	0
R	1	1	0	1
S	0	0	1	0

temp[3][3]

	P	Q	S
P	0	1	0
Q	1	0	0
S	0	0	0

Sum[1]=1
Sum[2]=1
Sum[4]=0

Fig.6 The working methodology of mechanism

From the fig.6 it is understood that the component "R" Cannot be removed as the first part. Hence the sub liaison matrix will not be analyzed further.

5. Results and Conclusions

The mechanism results the possible disassembly sequences is shown in Fig.7, as explained in Fig.6, it eliminates all the disassembly sequences(6) started with "R" at level-1, similarly four disassembly sequences are eliminated at level.2.

All the figures must be placed in the column wise, however the authors can use single column to place big figures provided that the template formatting must not change. The title of the figure is to be placed below the figures as shown. As the number of parts increases in the assembly (n), the number of assembly sequences increases exponentially (n!) and Cut-set method is very much helpful in eliminating the non-possible disassembly sequences and result possible disassembly sequences based on liaisons. The possible assembly sequences can be obtained by reversing the disassembly sequences.

1	P	Q	R	S	1	P	Q	R	S
2	P	Q	S	R	2	P	Q	S	R
3	P	R	S	Q	3	P	R	S	Q
4	P	R	Q	S	4	P	R	Q	S
5	P	S	Q	R	5	P	S	Q	R
6	P	S	R	Q	6	P	S	R	Q
7	Q	P	R	S	7	Q	P	R	S
8	Q	P	S	R	8	Q	P	S	R
9	Q	R	S	P	9	Q	R	S	P
10	Q	R	P	S	10	Q	R	P	S
11	Q	S	P	R	11	Q	S	P	R
12	Q	S	R	P	12	Q	S	R	P
13	R	P	Q	S	13	R	P	Q	S
14	R	P	S	Q	14	R	P	S	Q
15	R	Q	S	P	15	R	Q	S	P
16	R	Q	P	S	16	R	Q	P	S
17	R	S	P	Q	17	R	S	P	Q
18	R	S	Q	P	18	R	S	Q	P
19	S	P	Q	R	19	S	P	Q	R
20	S	P	R	Q	20	S	P	R	Q
21	S	Q	R	P	21	S	Q	R	P
22	S	Q	P	R	22	S	Q	P	R
23	S	R	P	Q	23	S	R	P	Q
24	S	R	Q	P	24	S	R	Q	P

Fig.7 Cut-set based disassembly sequences

The automated procedure explained in this paper is a direct implemented and tested on 3D CAD assembly. The integration of code with 3D CAD environment reduces the human error and results the all possible disassembly sequences without any human intervention. This procedure also reduces the time to extract the liaisons diagram from 3D CAD data and in generating all the possible disassembly sequences.

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