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An Automated Assembly Sequence Planning System

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Abstract

In this paper, a methodology called ASPS (computer-aided Assembly Sequence Planning System) was developed to incorporate making decisions on process planning and production planning for assembly product.

Using ASPS, a planner or manufacturing engineering can determine optimum or near optimum assembly sequence(s). The system has been tested on product a stapler and showed to increase efficiency of assembly line about 30%.

Keywords: decisions on process & production planning, assembly product, optimum assembly sequence planning

نظام التخطيط للتجميع المعان بالحاسوب

الخلاصة

في هذا البحث تم بناء وتصميم نظام(ASPS) (نظام التخطيط للتجميع المعان بالحاسوب) والذي طور لاتخاذ القرارات حول تخطيط العملية والتخطيط لتجميع المنتجات الميكانيكية.

استخدام هذا النظام من قبل مهندس التخطيط او التصنيع يمكنه من تحديد افضل تتابع لتجميع المنتج, افضل تخصيص لمهام التجميع الذي يعطي اعلى كفاءة لخطوط التجميع. تم اختبار النظام على احد المنتجات الميكانيكية وهو كابسة أوراق يدوية حيث أدى الى زيادة كفاءة خط التجميع بنسبة 30 %.

1- Introduction :

The assembly of products is the final step in the manufacturing process. For most products, assembly is done manually. The labors cost for assembly vary between 50% and 70% of the total labor cost for manufacturing the product. Optimization of the assembly process is therefore very important [1].

- Assembly planning is a fundamental step in the operation of a manufacturing system that involves product assembly. Assembly planning can be defined as follows:- The process that determines the sequence and method of putting component parts together to produce a product [2].
- The sequence of assembly tasks that starts in a state where all parts are unconnected and terminates in a state representing the final assembled product [3].
- It determines a sequence of assembling a product with respect to its geometric and resource constraints [4].
- It generates an optimum assembly plan from geometrical

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and topological information about the product [5].

The whole process of assembly sequence planning can be subdivided into three main steps, of which sometimes the first two steps are taken together:

1- Generate precedence relations between the components of a product.

2- Generate all feasible assembly sequences.

3- Find the optimal assembly sequences.

The sequence of tasks in which assembly is performed can have a significant impact on cost and efficiency through both quantitative and qualitative measures[6]. Quantitative measures may be derived from resource allocation, line balancing, scheduling. Qualitative measures or perhaps measures difficult to quantify may include ease and stability of assembly, fixturing requirements and complexity of operations [7]. Selection of a good sequence of assembly operations is a crucial factor in maximizing the production profitability and has great impact on the assembly line balancing [8]. Another study was developed a three-stage integrated approach with some heuristic working rules to assist the planner in generating a best and most effective assembly sequence and The results was showed that the assembly sequence optimization and allows the designer to recognize the contact relationship and assembly constraints [9].

2- System Development

The Automated Assembly Sequence Planning System for Mechanical Products (ASPS) is developed in this research so as to determine optimum or near optimum solution to assembly planning and lines balance is as integrated form, to fulfill the requirement of modern manufacturing environments. The (ASPS) also evaluates and analyses the generated assembly tasks sequence because determining a good sequence product assembly operations is a crucial factor in maximizing production profitability and assembly line balancing.

The ASPS is built by using visual basic language (version six) while integrated with Microsoft Access database environment. Figure (1) illustrates the depicted of the system methodology.

3- ASPS Characteristics

The main characteristics of the developed ASPS are: -

The ability to generate several sequences for sub-assemblies based on the input precedence matrix and then generating the final assembly sequence that satisfies the goals of minimum time & minimum cost. The result is obtained through interaction with the developed database that is based on representing of precedence diagrams.

Generation of final assembly plan through processing of above stage that gives the following results:

A- Optimal or near-optimal assembly sequence for final product and sub-assemblies.

B- Best assignment to assembly tasks dependant on the output required.

4-Methodology

Any assembly process can be decomposed into a set of assembly tasks, where each task involves joining two or more parts or subassemblies together and inspection processes and any process that is executed on assembly line. Assembly tasks (work elements) give a set of precedence constraints which exist due to technological requirements (e.g. a bolt should be put through the hole before the nut is put on). Some of these technological restrictions may be shown diagrammatically as in figure (2). Then the input precedence diagram is translated by the system into precedence matrix as shown in figure (3).In the matrix:

Tij = +1 if the element i must-precede the element j .

Tij = -1 if the element i must-precede the element j.

Tij = 0 no relationship between element i and element j.

where: i= Rows number = Assembly Tasks.

j = Columns number = Assembly Tasks.

The representation for assembly tasks of a product must be complete and correct, figure (4) shown a assembly sequence representation module. An assembly which fulfills some specified functional requirements is called a product. The difference between a sub-assembly and a product is not that clear. For one department an assembly may a product (e.g. a complete engine), whereas for another department this product may be sub-assembly (e.g. the engine assembled in a car). So the developed system generated sequence for the product whether it is a sub-assembly or final product. The (S.G.) Module can be executed through the following steps:

1- Determine task group name and call (S.R.) module.
2- Finding Assembly Sequences Probability, If there are N assembly tasks, there are potentially *N! (N factorial)* different possible sequences to assemble them. In reality some assembly tasks must be assembled prior to other thus the number of possible assembly sequences is usually much less than *N!*.
3- Depending on precedence constrains filtering of sequences probability is carried out. Final assembly sequences are the displayed. Figure (5) shows Assembly sequences Generation (S.G.) module

4- The ASPS Testing:

One of the case studies developed in this research is a stapler. Figure 6 shows the parts and the assembly of a stapler. In this process planning, 30 assembly unit operations are assigned at the assembly line. Assembly unit operations and their task time are presented in Table 1. the customer demand (or output per day) is 720 units, and production time per day is 28800 Sec (8 hours). Therefore cycle time is 40 Sec.

Cycle time =Production time per day / Customer demand …… (1)

C= 28800 Sec (8 hours) / 720 units = 40 Sec

Efficiency = Total Task Time / (Actual number of workstations * C) ….. (2)

Before applying the system (ASPS), E = 407.68 / 15 * 40 = 0.679

Examining and testing the capabilities of the developed system are carried out through the selection of stapler assembly as an example for testing the system. Table (2) show the Result for stapler assembly sequence planning.

After applying the system (ASPS), assembly line has ten workstations therefore the efficiency of assembly line is 0.981

6- Conclusions

1. The choices of assembly sequence without the aid of computer is are very difficult for two reasons.

A. the number of valid sequences can be large even at a small parts count

and can rise with increasing part count.

B. second minor demand of product changes can modify the available

choices of assembly sequences.

2. The assembly process is generally constrained by particular characteristics of the process itself, of the system and of component parts of the product. These technological constraints may include:

A. maximum number of fixture that can be used.

B. maximum number of assembly operations that can be executed in parallel.

C. maximum number of workstations.

3. The opportunity to group assembly operations at one workstation criteria is considered assembly tasks requiring the same facility so they must be grouped together.

4. The objective of this criterion is to minimize the fixtures used and / or maximize tool sharing or them.

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Table.1 Unit operations for stapler assembly

Number	Assembly unit operation	Task time (s)
1	Checking support surface	8.60
2	Testing slider movement	12.54
3	Attaching slider link to slider	10.42
4	Attaching brand tag to support	19.20
5	Attaching warning tag at body	8.60
6	Attaching support spring to support	44.46
7	Setting the slider in the guide assembly	15.00
8	Joining press and body	18.00
9	Joining upper guide and body	29.60
10	Testing slider link rotation in slider	11.50
11	Testing guide assembly surface	16.66
12	Joining guide assembly and body	5.42
13	Gripping guide assembly in the machine	12.40
14	Checking body surface	24.40
15	Checking press surface	14.00
16	Deburring body	11.44
17	Deburring support	10.86
18	Testing body locking in body	11.60
19	Attaching slider link to upper guide	6.58
20	Join body and support	8.80
21	Contacting pad to support	13.40
22	Deburring press	27.84
23	Testing guide assembly locking in body	10.42
24	Checking pad surface	19.20
25	Attaching warning label at support	10.76
26	Contacting pad locking spring unit	12.42
27	Joining pad and support	5.36
28	Checking support spring	11.20
29	Testing body rotation in support	9.20
30	Testing slider link rotation in upper guide	9.80

Table 2. Result for stapler assembly sequence planning

Work Station	Sequence	Assembly Unit Operation	Task Time	Worker	Total Task Time
1	1	Checking support surface	8.60	1	31.06
	6	Attaching support spring to support	22.46		
2	11	Testing guide assembly surface	16.66	1	35.86
	24	Checking pad surface	19.20		
3	7	Setting the slider in the guide assembly	15.00	2	46.82
	12	Joining guide assembly and body	5.42		
	13	Gripping guide assembly in the machine	12.40		
	15	Checking press surface	14.00		
4	3	Attaching slider link to slider	10.42	1	32.72
	16	Deburring body	11.44		
	17	Deburring support	10.86		
5	2	Testing slider movement	12.54	2	46.06
	10	Testing slider link rotation in slider	11.50		
	18	Testing body locking in body	11.60		
	23	Testing guide assembly locking in body	10.42		
6	5	Attaching warning tag at body	8.60	1	36.44
	22	Deburring press	27.84		
7	9	Joining upper guide and body	29.60	2	40.36
	25	Attaching warning label at support	10.76		
8	4	Attaching brand tag to support	19.20	2	45.02
	21	Contacting pad to support	13.40		
	26	Contacting pad locking spring unit	12.42		
9	8	Joining press and body	18.00	2	59.14
	19	Attaching slider link to upper guide	6.58		
	20	Join body and support	8.80		
	27	Joining pad and support	5.36		
	28	Checking support spring	11.20		
	29	Testing body rotation in support	9.20		
10	14	Checking body surface	24.40	1	34.20
	30	Testing slider link rotation in upper guide	9.80		

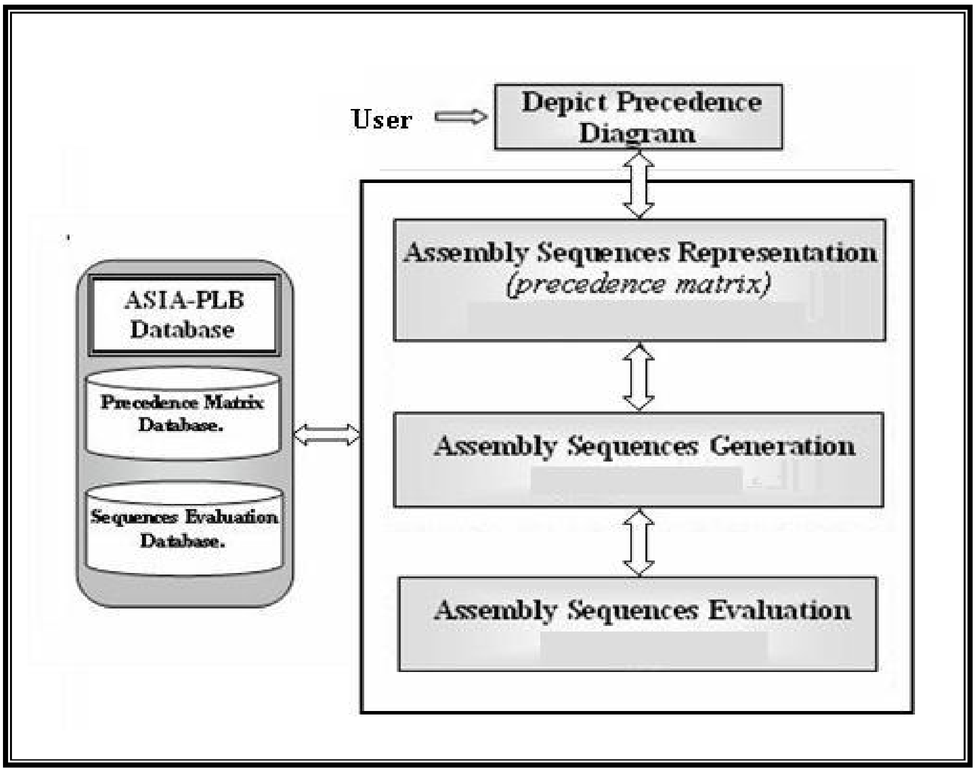


Figure (1) Depicted of The System Methodology

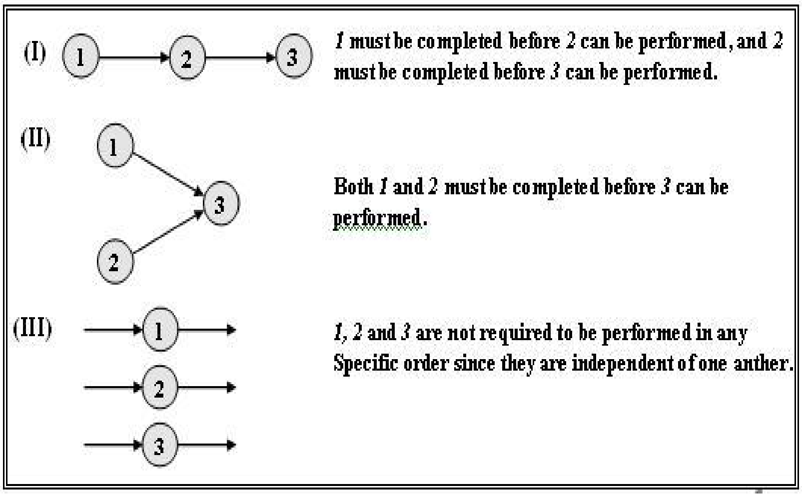
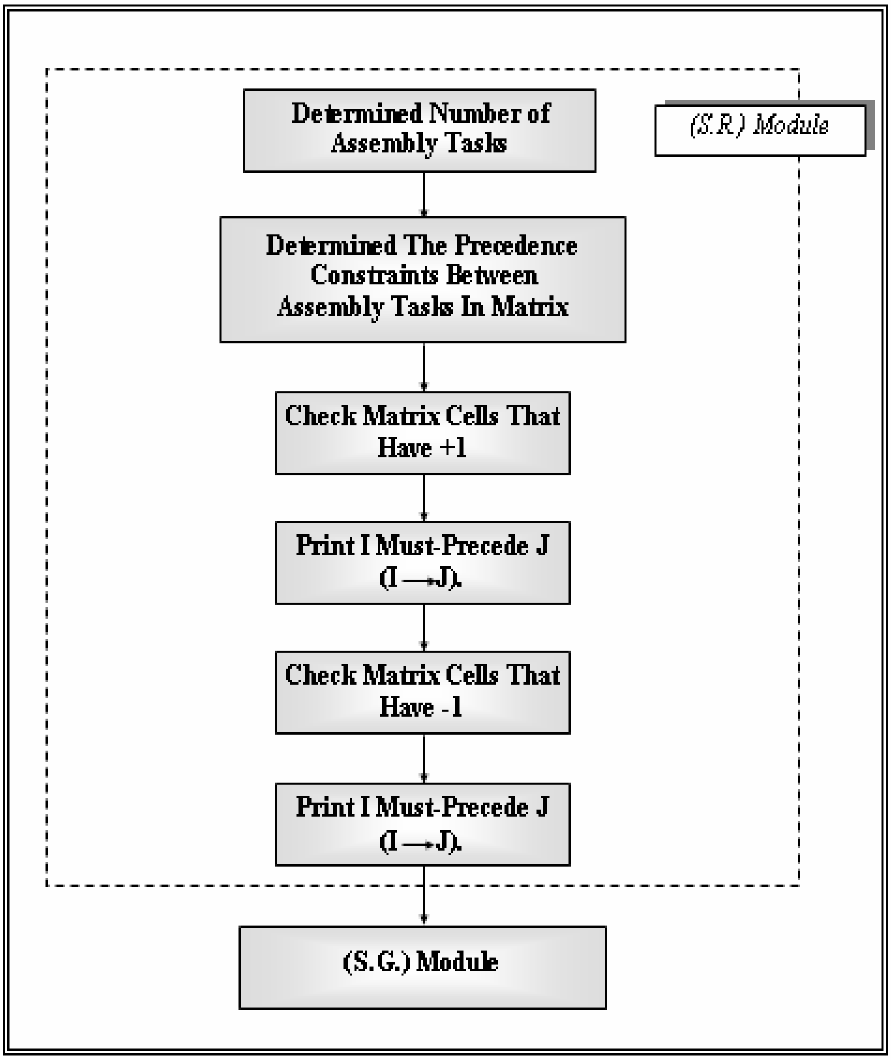


Figure (2) Type of Precedence Constraints

	T1	T2	T3
T1	0	1	1
T2	1 -	0	0
T3	-1	0	0

Figure (3) Precedence Matrix for n-tasks Problem II



Figure(4) Assembly Sequence Representation Model (S.R)

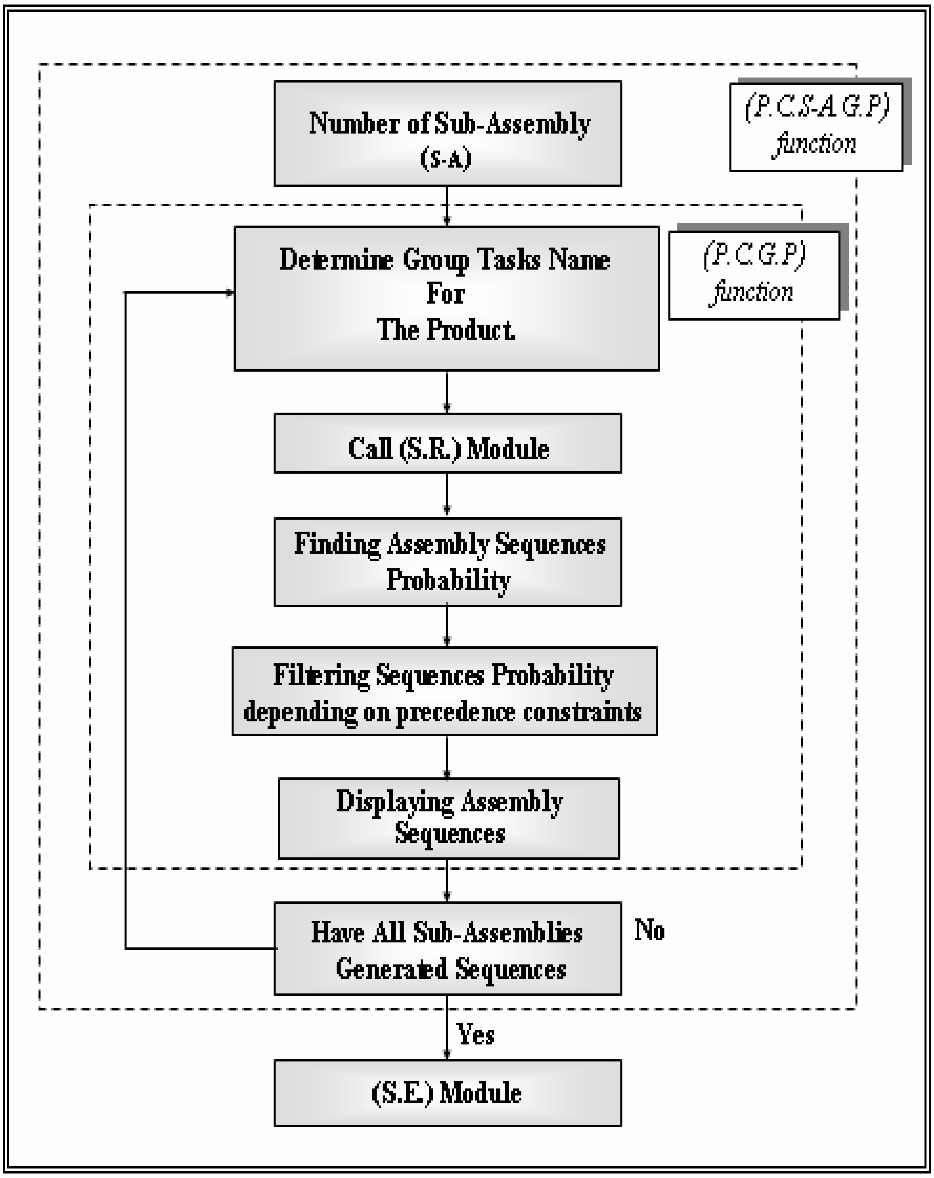


Figure (5) Assembly Sequence Generation Module (S.G.).

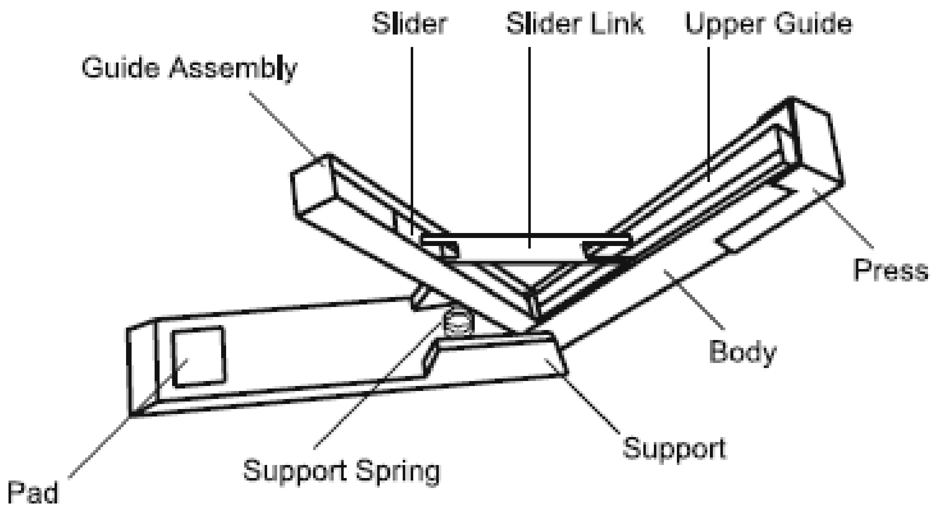


Figure (6) Parts and their assembly of a stapler