Simultaneous Scheduling of Assembly and Production Shops Using GA based Heuristic

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Abstract--- *This paper addresses a scheduling problem in an industry that manufactures machines. The manufacturing facility of the industry consist of two sections namely production shops and assembly shops. Production encompasses four subsections in it. Production shop is commonly shared by the components of different machines. But the assembly shops have independent section for each machine. Due to the sharing of production shops the components are not delivered in time to the assembly shop which delays the assembly of a product. The above problem is addressed by simultaneously scheduling the production and assembly shops with an objective criterion of minimum penalty cost. The production environment is of job shop in nature. The schedule generated accounts the alternative routing as it increases the flexibility in scheduling. Job shop problem are combinatorial optimization problems, account of alternative routing increase the complexity of the problem. The above problem becomes NP hard in nature. Meta heuristics are evolving as a promising alternative to address the NP hard problems. Genetic algorithm one among the Meta heuristic is used to evolve the simultaneous schedule of production and assembly shops and it is illustrated with the different products models developed to represent the machines of the company.*

Keywords--- *Scheduling, Meta- heuristic and Genetic Algorithm.*

I. INTRODUCTION

Manufacturing industries of today need to produce quality products with economy and to deliver with out any delay; this situation has leaded to the companies to focus on every activities or operation. An overall plan is needed to follow the operations effectively and it is a result of decision taken at various levels of operation. Good decision provide good plans and hence increased productivity .Production schedule is an important decision making process at shop floor operation level. This paper addresses a scheduling in manufacturing industry which produces capital goods. Industries of such nature have production and assembly shops. The components or parts that make up a assembly are manufactured in production shops and assembled to form a product in assembly shops. The general job shop problem is one of the well known machine scheduling problems, in which the operation sequence of the jobs are fixed that corresponds to their optimal process plans or resource availability . However the use of other possible process plans in addition to optimal one could provide better schedules resulting through reduced bottlenecks and increased flexibility. Jawahar et al[1], proposed a GA based heuristic for scheduling problem of flexible manufacturing systems associated with alternate routing. They have shown that GA based heuristic search procedure is suitable for FMS scheduling problems and is capable to handle alternative route choice and to revise the

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schedules in real time operation with reasonable computation time. Willhelm and shin[2] investigate the effectiveness of alternative operation in flexible manufacturing systems. They showed via computation experiments that alternate operation could reduce flow time while increasing machine utilization. Hankins[3] also discussed the advantage of using alternate machine tool routings to improve the productivity. They show, through an example that using alternate machine results in reducing lead time and in improving overall machine utilization. In this concern this paper addresses the problem of scheduling jobs associated with multiple routing.

The job shop problem associated with multiple routings can be described as ; there are set of machine and set of jobs consist of chain of operations, which need s to be processed .Each operation can processes in one or more than one machine. How ever processing time or costs differs with machine features. Further the scheduling has to be extended to the assembly shop also. This problem is very hard to solve because the sequence of operation on job is pre specified and combinatorial in nature. Because of its inherent difficulty heuristic procedure are attractive alternatives. Most of the conventional heuristic procedures use a dispatching rule under the situation of choosing the operation from unscheduled operations. In recent years better solution approaches such as Genetic Algorithm (GA), Ant colony optimization (ACO), particle swarm optimization (PSO),and Tabu search have been attempted . GA is among such attempt and has been applied in variety areas of decision – making including many scheduling problem. On the above consideration, a GA, one of the most popular meta heuristic, is proposed for the scheduling problem under discussion. The GA is structure to evolve the optimal route choices for all the operations and schedule for minimum penalty cost criterion. The rest of the paper is organized as follows : section 2 describes the problem ; proposed GA is explained and illustrated in section 3 & 4 respectively ; the performance of the proposed methodology and scope for future work are discussed in the concluding section.

II. PROBLEM DESCRIPTION

2.1 Model of The Problem

The following notations are used to represent the production shops and assembly shops in the manufacturing facility.

C_{pi}:index for number of components of a product.

C^{sap}: index for number of components o f a particular subassembly in aproduct.

D: index for due date.

i: Index for component/part.(i =1,2,3……….I)

j: Index for operation (j= 1,2,3,4 ………J)

k: Index for machine.(k = 1,2,3 ………..K).

R: Index for route of particular operation.

l_p: Index for number of levels in the product

p: Index for product (p = 1,2 3………P).

P_c: penalty cost for a product

Sa_p: Index for subassembly in a product

(sa = 1,2,3,………Sa).

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t_{ijk}: Index for processing time in machine for particular operation in a component.

t^{sap} : Index for assembling time for particular assembly in a product.

F : Finishing date of the product.

2.2 Production Environment

The production shop consists of four sections. The machines in the respective division are assigned a number to identify it. The machine in the machining section is named as k1, K2, k3and k4. The machine in the sheet metal section is named as k5, k6 and k7. The machines in the welding section are named as k8 and k9. The machine in the paint shop is named as k10, k11, and k12. The parts that forms the assembly of a particular machine get processed at a particular division based upon the nature of operation desired. The part that gets processes at a particular division finally arrives at painting shop for painting operation. Once all the operations of a part are over they are moved to their independent assembly shop to assemble them into a product. All the parts that make up the assembly are brought to one place and assembled to form a product. The production division represents 'I' jobs which are to be processed on k machine which resembles a 'job shop type of scheduling'. Assembly also resembles a job shop type. Thus the production environment is identified as a job shop type.

2.3 Operation Environment

Every part consists of some number of operations associated with it. All the operations are carried out on the job to form a desired component or part. The summation of all the processing time of operations of particular components gives the flow time of a part or component. Every operation can be performed at different machine with different processing time, this leads to the account of alternative routing. Alternative operation could be used if one machine tool is temporarily overloaded while another is idle. The alternative routing is useful where the capacity problem arise. Even though alternative operations may incur penalties, they may be used to offload bottleneck machines with the objective of balancing machine utilization and expecting the flow of work pieces. Wilhelm and shim performed a study to investigate the effectiveness of alternative operations in flexible manufacturing systems. They showed via computational experiments that alternate operations could reduce flow time while increasing machine utilization. Hankins also discussed the advantage the advantage of using alternative machines results in reducing productivity. The time taken for completing particular operation inclusive of setup, processing and material handling time are termed as processing time.

While considering the assembly, the assembling of parts into particular assembly is accounted as operation. The time associated with operation of assembling is termed as "Sub assembling time ".

2.4 Objective

Determination of optimal production plan (Schedule for both production and assembly division s) for minimum penalty cost of delays.

2.5 Assumptions

The system consists of 'k' machines and 'i' different jobs. All jobs are processed under predetermined technological order given in the process plan. Each of the operation can be processed on a number of alternatives, non-identical machine. The detailed assumptions are:

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- Jobs are independent and consist of strictly ordered operation sequences; no priorities are assigned to any jobs here.
- Jobs preemption (or) cancellation is not allowed
- A given operation can be performed by one or more different non –identical machines
- Set up times is independent of operation sequence and are included in processing time.
- All jobs are simultaneously available at time zero.
- After a job is processed on a machine it is transported to the next machine immediately and the transportation time is negligible.
- Each operation has a decision work content and operational time
- At most one operation can be processed on one machine at the same time.
- Outsourced components are available at the time of assembly
- The common components or parts that belong to separate machines are produced in different lots.

2.6 Problem Statement

The above problem is addressed by determining an optimal schedules simultaneously for the jobs associated with multiple routing in production shop and assembly shop that has independent assembly lines in a job shop type environment given the processing time of all operations of their multiple routing, operation precedence constraints of all jobs and the assembling time of all the subassembly of a product.

III. PROPOSED METHODOLOGY

The different modules of the GA that is proposed to evolve simultaneously the optimal route choice for the operation and schedule for the shop problem associated with alternative route choices is outlined as flow chart given in fig1

3.1 Input Module

The data pertaining to the problem are: Number of machines in the shop (k), number of products (p); number of components/part (i); number of operation for all jobs (j_i); number of components in a product; number of levels in product structure; number of components of a subassembly; number of subassembly of a product; route choices along with machine number and processing time for all operations. The above data are given as input.

3.2 Initial Population Generation Module

A set of chromosomes equal to assumed size of the population (here 10) is randomly generated in this module. Each chromosome is a representation of route choice and operation sequence priority indicators for all the operations and comprises of two parts. The genes of the first part of the chromosomes represent route choices of the operations of all jobs and number of such genes is equal to the total number of operation of all jobs. the second part of the chromosomes with as many number of genes equal to total components, represent the priority of one component over the other component for loading. Genes,1 gene for 1operation and so on, provide priority number for their corresponding component.

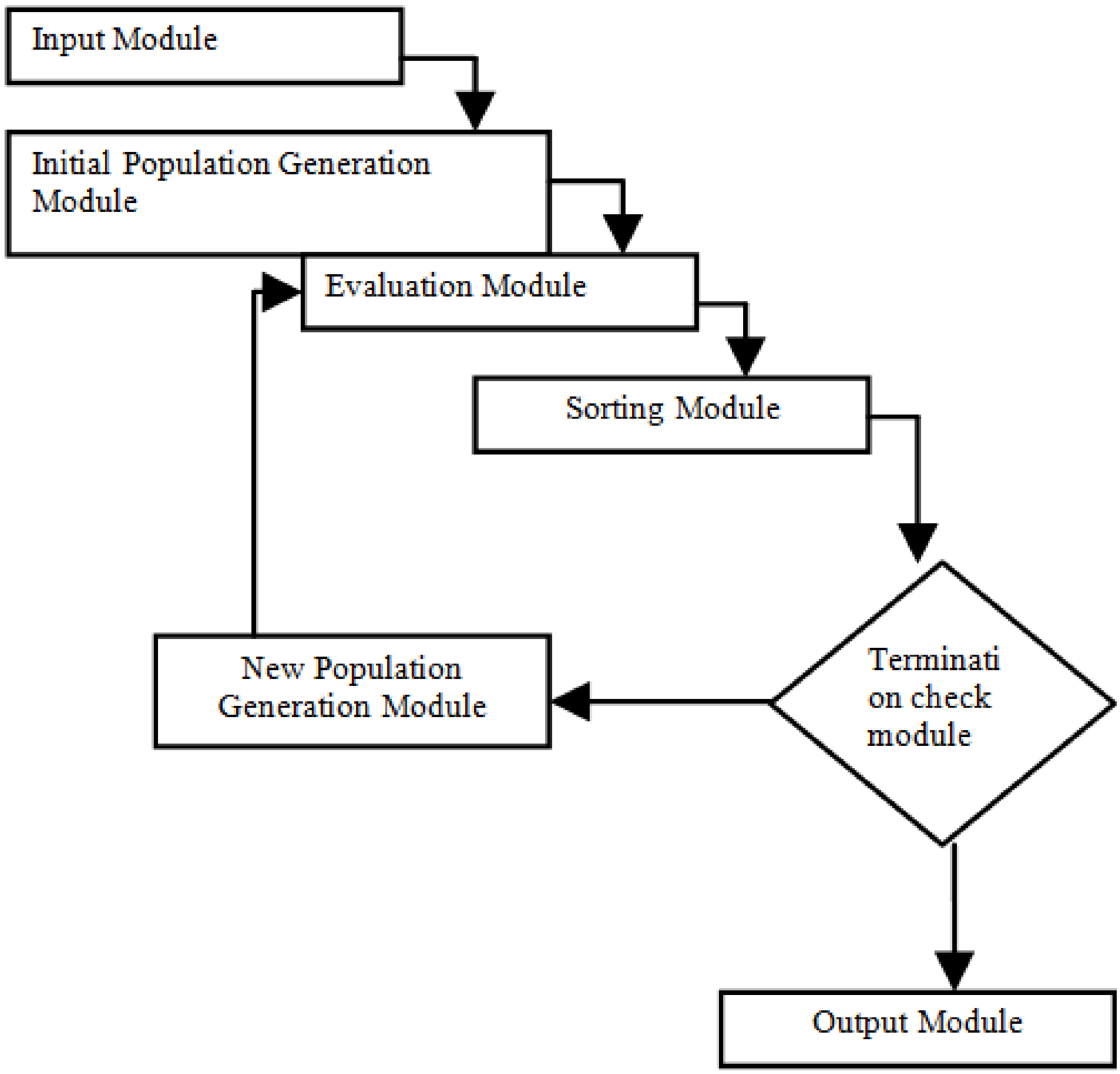

Figure 1: Procedure for GA

3.3 Evaluation Module

The active feasible schedule, one corresponding to one chromosome, of the current population are found using (i) the first parts of the chromosomes for reducing alternate route choice problem to fixed route choice problem and (ii)the second parts of the chromosomes to resolve conflicts that arise during the schedule generation with Giffler and Thomson algorithm. The penalty cost is taken as fitness value (fit (c)) of it.

3.4 Sorting Module

The best solution of the current population and the global best are sorted and stored separately.

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3.5 Termination Check Module

The convergence of the solution to optimality is checked so as to terminate the program. Usually, a specified number of generations (iterations) are used to terminate the GA. On satisfactory termination, the output module prints the optimal solution stored at the sorting module.

3.6 New Population Generation Module

A new population size equal to previous, is generated using the roulette wheel selection based on the probability of survival concept, cross over with probability of cross over(p_cross) as 0.6 and PMX cross over operator, and swap and cyclic mutation with the probability of mutation(p_mut)as 0.05

3.7 Output Module

Print the global best solution of: optimal route choices of all operation and schedule for minimum penalty cost.

IV. ILLUSTRATION

To have insight over the proposed GA methodology, an illustration is given in this section

4.1 Product Structure

Consider that there are three products to be produced. The figures 2,3&4 show the structure of them. Eighteen components are to be produced sharing the facility in the production shop. Table I provides the processing data such as number of operations, routé choice and its corresponding, M/C number for each operation, process time of all operation.

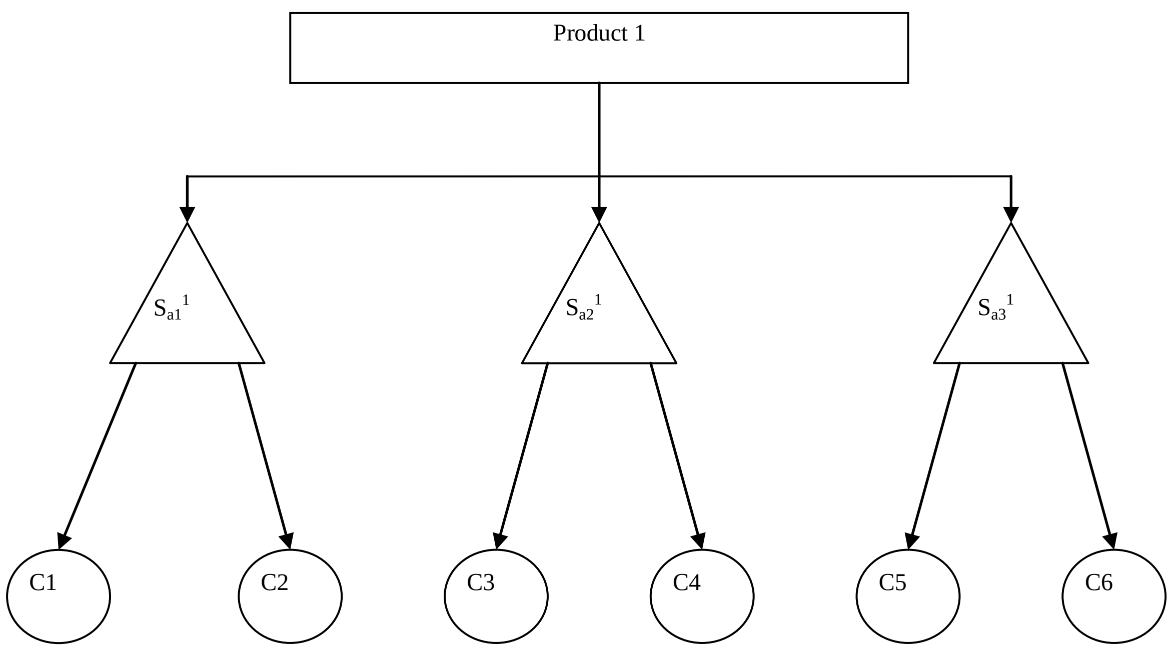

Figure 2: Product Structure1 having Two Levels in its Assembly

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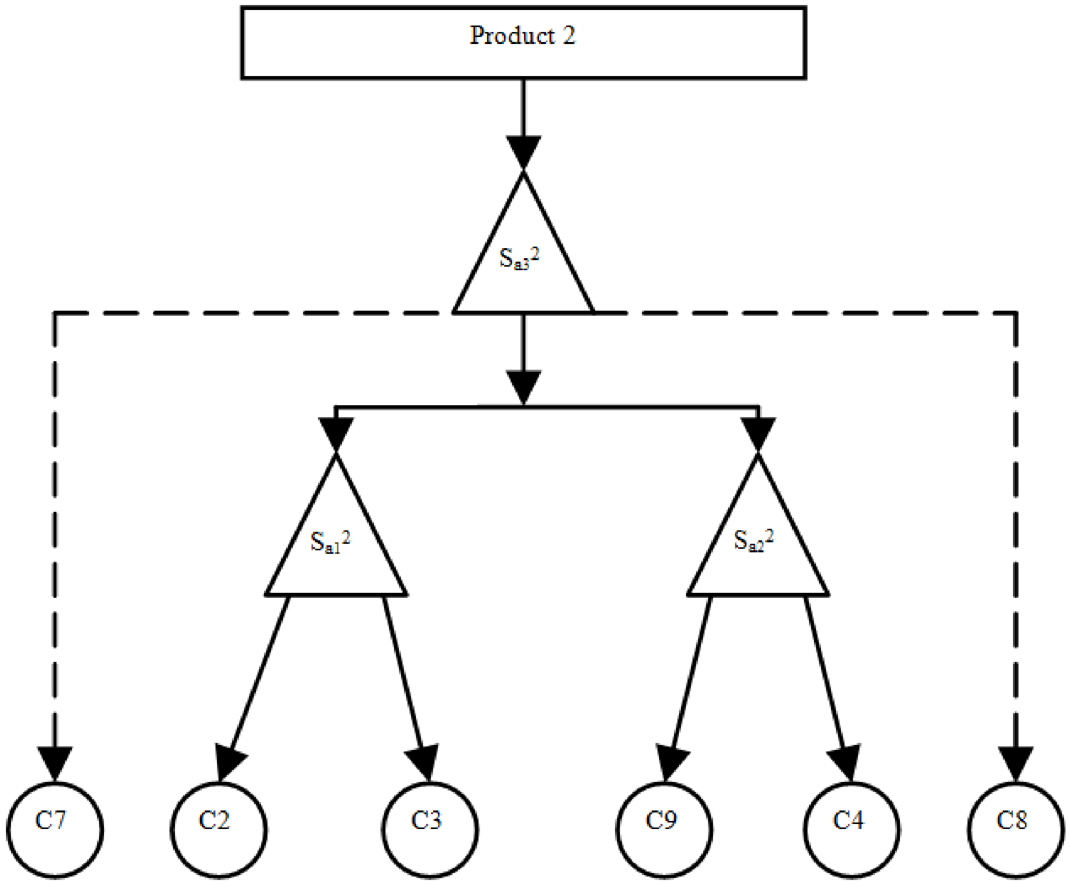

Figure 3: Product Structure2 having Three Levels of Assembly

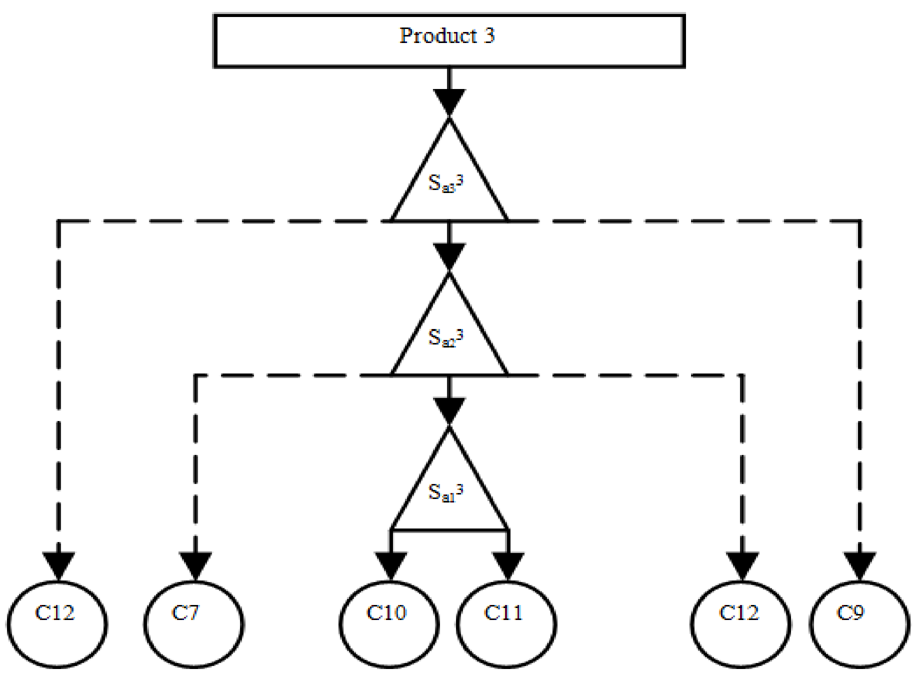

Figure 4: The Product Structure3 Showing Four Levels of Assembly

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The data's relevant to the three structure are represented in the table 1. the table gives the detail about various component of the product; number of operations involved in making a component; route choices of an individual operation; processing time for particular route choice in a particular machine; the number of components required for a subassembly and the sub assembling time.

Table 1: Details of the component that go into different products assumed above it consist of the following: number of jobs; number of operation; the route choices of the operation; and their processing time

Job number index i	Number of operation of a job and their route choice with processing time			
	1	2	3	4
1	R1=k1(5) R2=k2(3) R3=k4(5)	R1=k1(4) R2=k2(4) R3=k3(5)	R1=k2(3) R2=k3(4) R3=k4(5)	R1=k10(5) R2=k12(4)
2	R1=k2(4) R2=k3(5)	R1=k3(5) R2=k4(6)	R1=k5(6) R2=k6(7)	R1=k10(6) R2=k11(5)
3	R1=k7(8)	R1=k8(9)	R1=k10(5) R2=k11(3)	
4	R1=k1(5) R2=k2(6) R3=k3(4)	R1=k2(6) R2=k4(5) R3=k3(4)	R1=k5(8) R2=k6(7)	R1=k10(6) R2=k11(5)
5	R1=k1(5) R2=k3(2) R3=k4(5)	R1=k2(5) R2=k3(4) R3=k4(6)	R1=k4(8)	R1=k10(6) R2=k11(5)
6	R1=k1(5) R2=k2(6) R3=k3(7)	R1=k3(8) R2=k4(7)	R1=k10(6) R2=k11(5)	
7	R1=k1(7) R2=k2(8)	R1=k5(8) R2=k6(5)	R1=k12(8)	
8.	R1=K1(9) R2=K2(8)	R1=K3(4) R2=K4(5)	R1=K5(8) R2=K6(15)	
9	R1=K1(10)_ R2=K2(12) R3=K3(14)	R1=K3(5)	R1=K5(8) R2=K6(8)	
10	R1=K1(8) R2=K2(9) R3=K3(10)	R1=K3(9) R2=K4(9)	R1=K12(10)	
11	R1=K2(9) R2=K4(6) R3=K3(5)	R1=K5(8) R2=K6(6)	R1=K5(6) R2=K6(4)	
12	R1=K7(10)	R1=K8(14)	R1=K9(18)	R1=K10(6) R2=K11(5)

Table 2: Details of the assembly of a product1

Level2 activities	Processing time	Level 1 activities	Assembly time	Total time taken for a product.
C1 C2	20 24	1sa1	5	32
C3 C4	22 26	1sa2	6	
C5 C6	25 21	1sa3	7	

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Table 3: Details of the Assembly of a Product2

level3 activities	Processing time	Level 2 activities	Assembly time	Level 1 activities	Assembly time	Total processing time
C2 C3	24 22	2sa1	4			36
C4 C9	26 33	2sa2	5			
C7 C8	24 30			2sa3	6	

Table 4: Details of the Assembly of Product 3

Level 4 activities	Processing time	Level 3 activities	Assembly time	Level 2 activities	Assembly time	Level 1 activities	Assembly time	Total time.
C10 C11	29 23	3sa1	5					58
C12 C7	24 48			3sa2	6			
C9 C12	33 48					3sa3	4	

Table 5: Initial Population and their Corresponding Penalty Cost

Chromosome **C**	Operation sequence string	Job priority string	Penalty cost fit(C)
1	3311211111222212121222 1121113322211211212121 1 22 11111311111112	11 2 6 15 12 8 7 17 3 13 4 16 1 9 10 14 18 5	690
2	1311211111212212121222 121111211 1311121222221 322 12111112111111	11 2 6 15 18 8 7 12 3 13 4 16 1 9 10 17 14 5	1230
3	3311212111121221212222 2221111211 13121211122 21321 11111112111111	11 2 6 15 12 8 7 17 3 13 10 14 4 18 16 9 1 5	2220
4	331121111112222121222 11211112312 2112121211 221321 11111111121112	16 13 14 11 5 4 9 7 8 112 10 15 6 2 17 18 3	810
5	32112121111212212 12122 2221111211131221212221 32111111112111111	11 2 6 15 12 8 7 17 3 1 4 14 10 1 16 9 18 5	830
6	332121211112222121222 1121111231211122121 12 213211 1111111121111	13 16 14 11 5 4 9 7 15 12 18 8 17 2 6 10 3	1810
7	3331211111121121 21222 11211112312 1112212112 213211 1111111121111	15 16 14 11 5 4 9 7 8 112 10 13 17 2 6 18 3	550
8	3311211111122221 2122211 211112312 11122121122132 111111111121111	13 16 14 15 5 4 9 7 8 112 10 11 17 2 6 18 3	670
9	3311211111122121 212221 1211112312 11122121122 13211 1111111121111	13 16 14 11 5 4 9 7 8 112 10 15 17 2 6 18 3	610
10	3311211111122221 2122211 2111123121111212121 1221 321 11111111111111	13 16 14 11 5 4 1 7 8 912 10 15 17 2 6 18 3	640

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The best solution of this generation corresponds to chromosome 1, which is stored as instant best and replaces global best if it is better than previously stored global best. As two hundred number of generation of new population is fixed as termination criteria, the next population is generated.

The parameters used for the generation of new population are as follows:

Probability of survival p(c) of chromosome ‘c’

$$:e^{-xfit(c)} / \sum e^{-xfit(c)}$$

Constant ‘x’ value: 0.05

Probability of crossover ‘P_cross’ : 0.6

Crossover operator: Partially Mapped crossover

Probability of Mutation ‘p_mut’ : 0.05

Mutation operator: Swapping.

The process of evaluation, sorting and new population generation is repeated for 200 generations, which is the termination criterion. The best solution evolved is given below.

Optimal Solution

Job 1: Op1: 13-16(on2) Op2: 16-20(on2) Op3: 32-37(on4) Op4: 37-41(on12)

Job 2: Op1: 0-5(on3) Op2: 19-25(on4) Op3: 25-32(on6) Op4: 32-38(on10)

Job 3: Op1: 28-36(on7) Op2: 47-56(on8) Op3: 56-61(on10)

Job 4: Op1: 0-5(on1) Op2: 5-10(on4) Op3: 10-18(on5) Op4: 18-29(on10)

Job 5: Op1: 37-42(on4) Op2: 42-47(on2) Op3: 47-55(on4) Op4: 55-60(on11)

Job 6: Op1: 12-17(on1) Op2: 25-32(on4) Op3: 32-37(on11)

Job 7: Op1: 9-13(on2) Op2: 13-18(on3) Op3: 18-25(on6) Op4: 38-44(on10)

Job 8: Op1: 20-28(on7) Op2: 38-47(on8) Op3: 47-52(on10)

Job 9: Op1: 17-22(on1) Op2: 22-28(on2) Op3: 28-36(on5) Op4: 37-42(on11)

Job 10: Op1: 22-32(on1) Op2: 32-37(on3) Op3: 37-45(on5)

Job 11: Op1: 5-12(on1) Op2: 12-17(on6) Op3: 17-25(on12)

Job 12: Op1: 39-48(on1) Op2: 48-52(on3) Op3: 52-60(on5)

Job 13: Op1: 0-9(on2) Op2: 10-19(on4) Op3: 25-35(on12)

Job 14: Op1: 5-10(on3) Op2: 32-38(on6) Op3: 44-48(on6)

Job 15: Op1: 32-39(on1) Op2: 39-44(on6) Op3: 44-52(on12)

Job 16: Op1: 0-10(on7) Op2: 10-24(on8) Op3: 24-42(on9) Op4: 42-47(on11)

Job 17: Op1: 28-40(on2) Op2: 40-45(on3) Op3: 48-56(on6)

Job 18: Op1: 10-20(on7) Op2: 24-38(on8) Op3: 42-60(on9) Op4: 60-65(on11)

The total time taken for all the components to be processed in the production shop is given in the result

Result=65.0

The assembly schedule is

Product1

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1-1-1=46; 1-1-2=67; 1-1-3=67; 1-2-1=79: completes by the 79th hour.

Product 2

2-1-1=56; 2-1-2=50; 2-2-1=66; 2-3-1=80: completes by the 80th hour.

Product 3

3-1-1=53; 3-2-1=59; 3-3-1=69; 3-4-1=85; completes by the 85th hour.

The delay is only on the product 3. The penalty associated with this delay is calculated and was found to be 150 units.

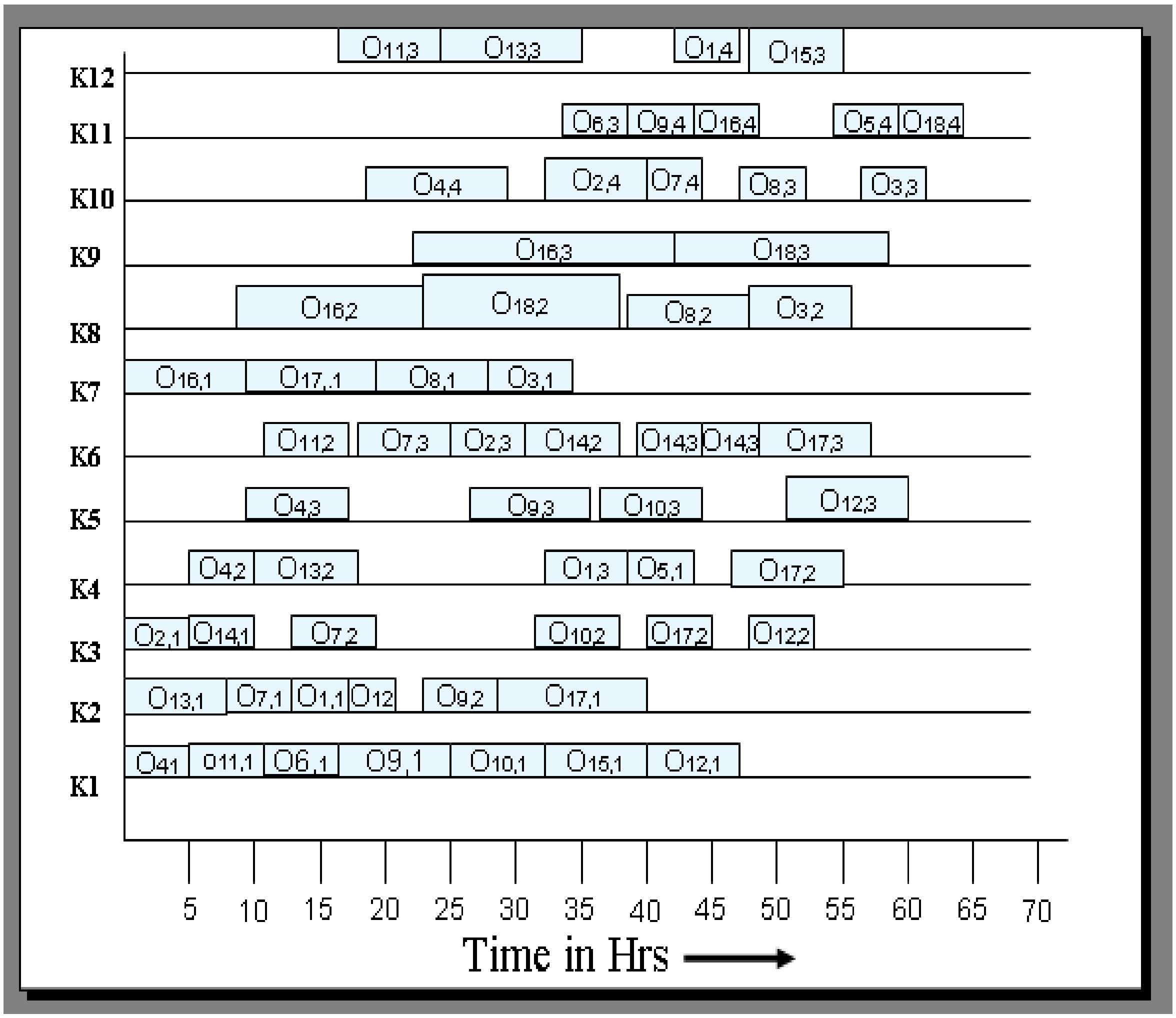

Figure 5: Gannt Chart Showing the Components Loaded on the Machine

V. Conclusion

A GA is presented and illustrated for the evolution of optimal route choice from possible routes and a simultaneous schedule for the production and assembly shops associated with multiple routing. The proposed GA is structured such that the coding could be used for any scheduling objectives .The parameter of GA need fine tuning for quick convergence towards optimality, which would save computation time.

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