Simulation applications in the automotive industry: sequencing production on an assembly line using goal chasing and user defined algorithm.

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SEQUENCING PRODUCTION ON AN ASSEMBLY LINE USING GOAL CHASING AND USER DEFINED ALGORITHM

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ABSTRACT

An Australian automotive component company plans to assemble and deliver seats to customer on just-in-time basis. It plans to assemble various seat types on one assembly line. Mixed-Model sequencing is very important if a company has to assemble seats in just-in-time environment. Toyota Motor Company's goal chasing algorithm I and a user defined algorithm are used sequence seats on assembly line. Discrete event simulation software is used to model the assembly operations of seat plant. Both algorithms are programmed to generate a sequence for the seat plant. Model results show both algorithms can sequence seats on the assembly line and each algorithm has its advantages and disadvantages.

1 INTRODUCTION

Air International is an Australian technology provider designing, manufacturing and distributing interior parts such as seating, air conditioning, steering systems and heating systems for automotive, rail, heavy transport and bus applications. Air International has planned a new seat plant to assemble car seats for a car company. The new plant is designed to assemble different seats on an assembly line.

The objective of the research is to determine a sequence of seats that maximizes operator efficiency for a given customer requirement.

Discrete event simulation Quest is used to model the operations of seat plant. The main aim is to develop an algorithm to level the workload among various workstations and find bottleneck workstations.

2 FRONT SEAT ASSEMBLY LINE

Car seats consist of front and rear seats. The block diagram in Figure 1 shows various parts of a car seat. Front seats and rear seats are assembled on two different assembly lines. This paper discusses seat sequencing on a front seat assembly line.

Seat assembly is done on a power and free conveyor-requiring operators at each workstation. Operators are the key resource in the seat assembly process. The front seat line is designed based on the forecast of seats for the first year of production with provision being made for future production.

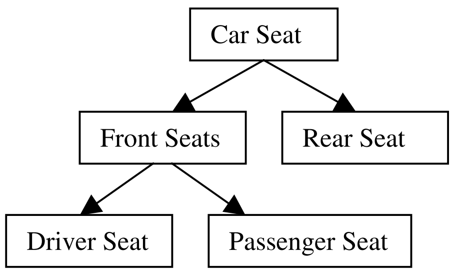

Figure 1: Car Seat Components

2.1 Process Plan

Front seat assembly is done sequentially and in parallel as shown Figure 2. Front seats are assembled on built fixtures. The first operation is placing seat tracks on a built fixture. The front seat cushion, back and head rest are assembled simultaneously and are made available on conveyors connected to main assembly line.

There are a total of 33 workstations on the front seat assembly line.

2.2 Seat Types

There are 40 different seats to be assembled on the front seat assembly line. Seats can be classified into three different types based on their features.

- Type 1 is a base seat
- Type 2 is a medium seat
- Type 3 is a luxury seat

More features means it takes more time to assemble a seat.

2.3 Assembly Times

Assembly time of key workstations on front seat assembly lines are shown in Table 1 below.

Table 1: Seat Assembly Time Matrix

Models Assembly Time in Seconds			
Seat Type	St 12	St 13	St 30
Type 1	45	100	60
Type 2	90	155	60
Type 3	90	155	120

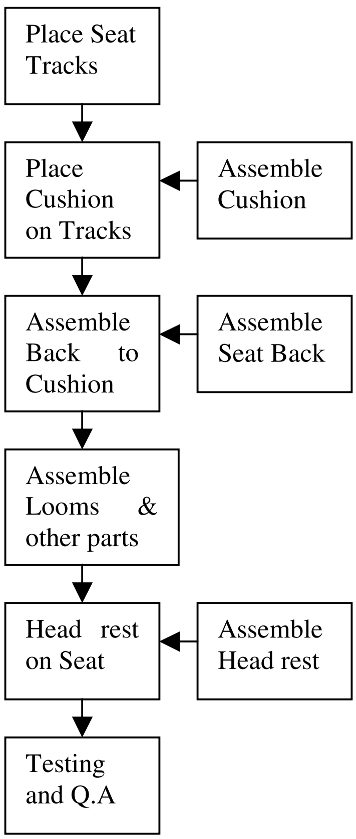

Figure 2: Front Seat Assembly Block Diagram

3 MIXED-MODEL SEQUENCING

Mixed-model sequencing can have various goals depending on the manufacturing environment. The objective of the mixed model can be defined by the first two points according to Monden (Monden 1998). They are:

- Leveling the load on each process within the line
- Maintain a constant usage of parts along the assembly line.
- Maximize throughput
- Minimize assembly line length

Objectives vary depending on the type of product, customer requirement and other constraints.

3.1 Mixed-Model Algorithms

Industries and researchers have developed many mixed-model algorithms. Some of the commonly used and referenced algorithms are:

- Goal Chasing Algorithm I (Monden 1998)
- Goal Chasing Algorithm II (Monden 1998)
- Miltenburg Algorithm (Miltenburg 1992), (Miltenburg 1989)
- Time Spread Algorithm (Sumichrast 1992)
- User Defined Algorithm

Goal chasing algorithm I is developed by Toyota Motor Company for JIT production. It is explained in detail by Monden (Monden 1998) in his book on Toyota Production Systems. Seat plant supplies seat to car company using JIT production system similar to Toyota Production System. So goal chasing algorithm is a good match to sequence seat production. Goal chasing algorithm finds a product sequence one position at a time by solving the objective function given below.

The algorithm has two objectives:

- Leveling the load (total assembly time) on each process within the line.
- Keeping constant speed in consuming each part on the line.

Goal chasing algorithm objective function is given by;

$$\textit{Minimize} \sqrt{\sum_{j=1}^{\beta} \left(\frac{KN_j}{Q} - X_{j,(k-1)} - b_{ij} \right)^2} \qquad (1)$$

Where:

K = the current position in the sequence

Q = Total production quantity of all models

c = the number of different components

N_j = Total quantity of parts j required to assemble all Q products

$X_{j,(k-1)}$ = the quantity of the part j required to assemble (k-1) units of the actual products

b_{ij} = the quantity of parts j required to assemble one end item i

For Q (total production quantity) objective function is solved Q times to generate a model sequence.

User defined algorithm is a set of rules sequencing seats similar to goal chasing algorithm. The first seat model was run using random schedules generated from customer forecast data to study seat line behavior. The goal of the study was to formulate a set of rules to sequence seats on front seat line. They are:

- Do not sequence type 2 and type 3 seats one after another.
- Sequence type 3 seat with at least 5 other type of seats in between.

These rules ensure seat line work load is distributed almost evenly all workstations to smoothen production and achieve output of 60 seats per hour.

Both algorithms are programmed in Quest to generate a sequence of seats.

4 MODELLING FRONT SEAT LINE

Front seat line modelling is done in five steps.

4.1 Objective

Develop an algorithm to level work load on all processes of front seat assembly line.

4.2 Data Collection

Data collection for the proposed seat plant is done in two parts.

Assembly times for each process were recorded during first batch build of seats. Approximately 2-3 number of each type of seats were assembled. An assembly time matrix of workstation assembly time and each seat type is constructed similar to one shown in Table 1

Number of operators, line speed, shift breaks were taken from the proposed design. Line stoppages times were collected from sister plant assembling seats for a different customer.

4.3 Model Building

The front seat line model is built in Quest simulation software shown in Figure 3.

The seat model is designed to assemble a maximum of 440 seats in each shift. Cycle time to assemble one seat is one minute. The customer notifies the seat plant on type and sequence of seats to be delivered. The seat plant plans to use a finished goods inventory to deliver seats on as soon as notification is received and then assemble seats that are pulled out of the FGI. Every hour 60 seats are sequenced to be assembled on the front seat line.

Figure 3: Front Seat Model

Two algorithms goal chasing algorithm I and a user defined algorithm are programmed in the model to sequence hourly production.

4.4 Verification and Validation

Model verification is done by measuring seat line output to confirm 1 seat is assembled every minute. The second step in verification is to confirm assembly time for each workstation and seat type matches assembly time matrix.

The front seat line is designed to assemble a mix of 70% type 1 and 30 % type 2 and 3. If the mix of type 2 and 3 seats is increased, line output is expected to drop. This is confirmed by the model. Based on the assembly time matrix it is possible to identify a bottleneck workstation. Validation confirmed the bottleneck workstation as its utilization was 100%. A group meeting with modelling team comprising of Plant Manager and line supervisor was held to demonstrate the model and confirm the behavior of the model was similar to a real one.

4.5 Experimentation

Seat requirements from the customer can be grouped into three type of seats. Forecast data indicates during any production hour a requirement of 50% type 1 and 50% of type 2 and 3 seats can be expected.

Hence seat requirement is a mix of three types of seats. Table 2 with different types of seat is generated after group discussion with modeling team.

Goal chasing algorithm and user defined algorithm program are used to sequence runs shown in Table 2. Seat line model is run using sequence generated by each algorithm and results recorded. Results are recorded shown in Table 2 under model output column. Results in Table 2 are from the user defined sequence. The first column indicates run number. The second column Seat requirement, represents the requirement for three types of seats and their total. Model output column lists the number of seats assembled on front seat line using user defined sequence after each run. Difference column indicates the difference between seat requirement total and model output total. The last two columns indicates type 1 and type 2 and 3 seats as a percentage of the total seats.

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Table 2: Model Run Data

Run	Seat Requirement				Model Output				Difference	Type1%	Type 2 and 3 %
	Type 1	Type 2	Type 3	Total	Type 1	Type 2	Type 3	Total			
1	40	16	4	60	41	16	4	61	-1	66.67	33.33
2	40	14	6	60	40	14	6	60	0	66.67	33.33
3	40	12	8	60	41	12	6	59	1	66.67	33.33
4	40	10	10	60	41	10	7	58	2	66.67	33.33
5	40	8	12	60	40	8	8	56	4	66.67	33.33
6	40	6	14	60	38	6	8	52	8	66.67	33.33
7	38	18	4	60	38	18	4	60	0	63.33	36.67
8	38	16	6	60	38	16	6	60	0	63.33	36.67
9	38	14	8	60	37	14	8	59	1	63.33	36.67
10	38	12	10	60	37	12	10	59	1	63.33	36.67
11	38	10	12	60	38	10	10	58	2	63.33	36.67
12	38	8	14	60	37	8	10	55	5	63.33	36.67
13	36	20	4	60	36	20	4	60	0	60	40
14	36	18	6	60	36	18	6	60	0	60	40
15	36	16	8	60	36	15	8	59	1	60	40
16	36	14	10	60	36	13	10	59	1	60	40
17	36	12	12	60	36	12	11	59	1	60	40
18	36	10	14	60	36	10	11	57	3	60	40
19	34	22	4	60	32	22	4	58	2	56.67	43.33
20	34	20	6	60	32	20	6	58	2	56.67	43.33
21	34	18	8	60	31	18	8	57	3	56.67	43.33
22	34	16	10	60	31	16	8	55	5	56.67	43.33
23	34	14	12	60	30	14	9	53	7	56.67	43.33
24	34	12	14	60	26	12	9	47	13	56.67	43.33
25	32	24	4	60	29	24	4	57	3	53.33	46.67
26	32	22	6	60	29	22	6	57	3	53.33	46.67
27	32	20	8	60	28	20	8	56	4	53.33	46.67
28	32	18	10	60	29	18	8	55	5	53.33	46.67
29	32	16	12	60	29	16	8	53	7	53.33	46.67
30	32	14	14	60	28	14	11	53	7	53.33	46.67
31	30	26	4	60	29	24	4	57	3	50	50
32	30	24	6	60	29	22	6	57	3	50	50
33	30	22	8	60	28	20	8	56	4	50	50
34	30	20	10	60	29	19	8	56	4	50	50
35	30	18	12	60	29	18	8	55	5	50	50
36	30	16	14	60	29	16	8	53	7	50	50

4.6 Analysis of Results

Results obtained from seat model for goal chasing and user defined algorithm are plotted on a graph shown in Figure 4 below.

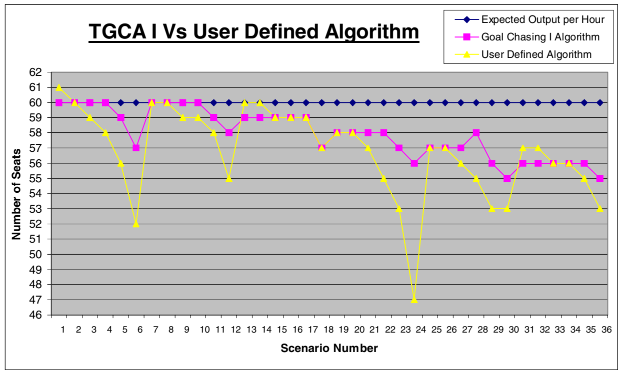

Figure 4: Comparison of Seat Output

As the seat mix between type 1 and type 2 and 3 increases from 66-33% to 50% each seat output goes down from 60 to 55 units. The seat output drop is expected because seat assembly line is designed to assemble a mix of 70% type 1 and 30% type 2 and 3. The graph shows for the user defined algorithm sharp drop in seat output at regular intervals while goal chasing algorithm shows a steady drop in seat output. Final analysis of the seat model is goal chasing algorithm sequences seats better than user defined algorithm for front seat line.

5 RESULTS AND DISCUSSION

Goal chasing algorithm is developed for a just in time production and has two goals; to level the load on an assembly line and maintain constant usage of parts. The second goal is more important than the first. Goal chasing algorithm sequences three type of seats evenly to achieve second goal of constant usage of parts. Hence when type 2 and 3 seats are 20 % of the total seat requirement they will be sequenced with equal intervals. In seat assembly line though the first goal is important. Hence a user defined algorithm was developed. User defined algorithm works on the principal of sequencing seats on a switch statement where if the mix is between run 1 and 6 a predefined logic is used to sequence seats. It does not sequence seats uniformly when type 3 seats are more as is the case in run 6. User defined algorithm can be modified to sequence each run in the table 2 on a predefined sequence. Other modification is to sequence seats in a predefined sequence when seat requirement is 70% type 1 and 30% type 2 or less than that. If type 2 and 3 seats requirement is less than 20 seats an hour it is of advantage to sequence type 2 and type 3 as early as possible with predefined sequence and sequence remaining type 1 one after another. Such a sequence would leave the line ready to respond if any rejection of type 2 or type 3 seats occurs during later stage of production.

In conclusion both algorithms are programmed and the decision is left to the production supervisor to decide which algorithm to use to sequence seats during any hour of production. Keeping the option of using both algorithms would give more flexibility in sequencing seats on a front seat assembly line as each algorithm has its advantage. It is possible in future each one may be used in different situations.

6 CONCLUSION

Mixed model algorithms are the key to just in time production systems. As customers demand user defined products it is difficult to assemble product in batches. The time required to deliver products is short and quality expectations are high. Good sequencing helps in distribution of work among all workstation to achieve higher utilization of operators and higher line output.

Both algorithms can be used to sequence seat production although goal chasing algorithm sequences seats better than user defined algorithm. User defined algorithm can be modified to include features like addition of user defined order, defining priorities to seat type etc.

Sequence generated by both the algorithms may not be optimum sequences but are good and are generated in a short span of time.

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