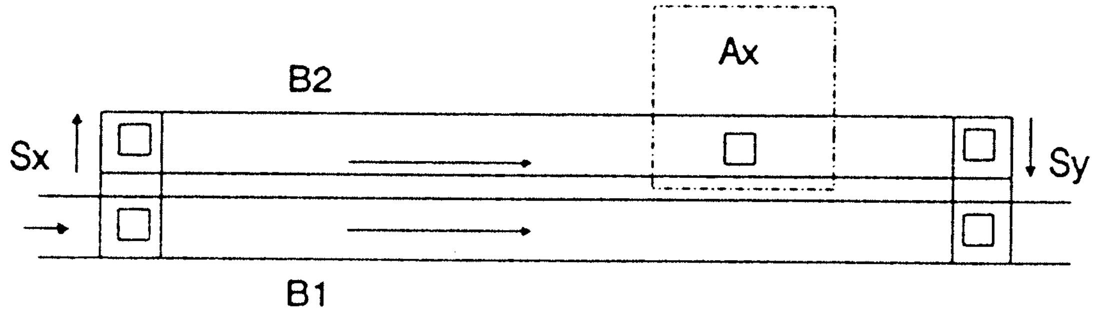
Comparison 2: Flexible Assembly System

The following example of a flexible assembly system has been chosen because it checks two important features of discrete event simulation tools:

- the possibility to define and combine submodels,
- the method to describe complex control strategies.

The model consists of a number of almost identical submodels of the following structure (figure 1):

Figure 1



Two parallel conveyor belts, B1 and B2, are linked together at both ends. An assembly station Ax is placed at B2. Pallets are coming in on belt B1. If they are to be processed in Ax they are shifted in Sx to B2 and possibly enter a queue in front of Ax. If there is no more empty buffer space on B2 or the pallet is not to be processed in Ax it continues its way along B1. Parts that have been processed in Ax are shifted back to B1 in Sy, having priority over those coming from the left on B1.

The total system now consists of 8 of these subsystems, varying in length, operation and operation time (see figure 2). Between two subsequent subsystems there is a space of 0.4 m, whereas pallets from the third subsystem A2 can be shifted directly to A3, and from A6 directly to A1. The shifting parts, however, cannot function as buffers, i.e. a pallet can only enter an Sx if it can leave it immediately.

Table 1 shows the operation time of each station, the total length of B1 and the length of the buffer in front of the station.

Table 1

Station	Operation time (sec.)	Length of B 1 (m)	Length of buffer in front station (m)
A 1	15	2.0	1.2
A 2	60	1.6	0.8
A 3	20	1.6	0.8
A 4	20	1.6	0.8
A 5	20	1.6	0.8
A 6	30	2.0	1.2

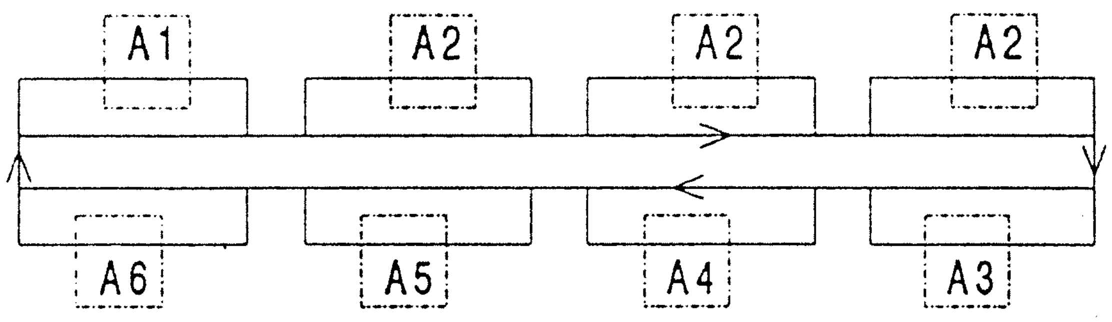
There are three identical stations A2 in the system, because the operation in A2 takes much longer than the other operations.

Unprocessed parts are put on pallets in A1. They can either be processed in A2 first, and then in A3, A4, A5, or in A3, A4, A5 first, and then in A2. The sequence of operations among A3, A4, and A5 is arbitrary. Station A6 is a substitute for any of the stations A3, A4, A5, i.e. whenever one of these stations is down, or the buffer in front of it is free, the corresponding operation can be executed in A6. Finished parts are unloaded in A1, unfinished parts enter another circle.

All conveyors are running with a speed of 18 m/min., any shifting takes 2 sec., and pallet length is 0.36 m. Assuming that no station ever has a breakdown, the optimum number of pallets in the system is to be found. Therefore the total throughput and the average throughput time of the parts have to be evaluated, when 20, 40, and 60 pallets are circulating in the system.

To simplify comparison of results we suggest starting simulation experiments with empty pallets and collecting data from the 120th to the 600th minute (8 hours).

Figure 2



Remarks

In number 1 of EUROSIM - Simulation News Europe (March 1991) we had proposed to test discrete event simulators using an example flexible assembly system. Some letters from readers however made it clear that the description of the system has been somewhat incomplete. We therefore try to answer the open questions and ask you not to hesitate to contact us if any other questions arise.

What follows is not a full definition of the model but only some details in addition to the description in EUROSIM - Simulation News Europe 1.

1. The subsystems contain two parallel conveyors B1 and B2. The total length of B2 between Sy and Sy is given in table 1. Sx and Sy themselves are 0.4 m wide. A pallet can either pass Sx or Sy without any delay with its normal speed along B1 or can be shifted to B2 in 2.0 sec. The lengths of B1 and B2 are the same. B2, however, is divided into three parts: the buffer in front of the station (its length being given in table 1), the station's positioning unit of length 0.4 cm, and the buffer behind the station (the remaining part of B2).

2. The conveyors themselves can function as buffers. Pallets can queue up in front of the stations or in front of Sx and Sy but the conveyor will move on with its normal speed. Also during the shifting of one pallet or while it is being processed on one of the positioning units in an Ax the other pallets are being transported without any delay. The capacity of each buffer can be easily calculated by dividing its length by the pallet length (0.36 cm). Of course, only integers are feasible results.

3. If the buffer in front of Ax is full, all pallets move on along B1 even if they require processing in Ax. They may either be processed when the pass Ax the next time, or they may be processed in A6 (if x = 3, 4, or 5).

4. The transportation time from Sx to Ax (i.e. its positioning unit) is not part of the operation time as given in table 1. The same holds for the transportation time from Ax to Sy.

5. In the beginning empty pallets are circulating in the system. Their positions on the conveyors B1 (not B2!) can be chosen randomly. Unprocessed pieces are put on them in A1 (operation time 7.5 sec), and finished parts are unloaded in A1, too (operation time 7.5 sec, hence total time for load/unload is 15.0 sec). A1 is only used for these load/unload operations.

6. Pallets are being brought to A6 if they have not undergone one or more of the operations of A3, A4, or A5. They can then undergo all the missing operations at a time.

We hope we have clarified the open questions now. Again: if any other questions come up during modelling, don't hesitate to contact us.

Finally we ask everybody who has tried or will try to model the system to send us a report on the experiences he/she has made even if no results have been achieved. We believe it is as important to learn why certain approaches or tools are not appropriate, as it is to learn how other colleagues have solved the problem. Unfortunately scientists do not communicate their unsolved problems and unsuccessful approaches as freely as they communicate their solutions. Please help us to change this and tell us if you have not been able to model this system with a simulation tool, and what the difficulties were. Thank you very much!

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