MONTE CARLO SIMULATION OF FULL CASE CONVEYING SYSTEMS

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SUMMARY

This abstract illustrates the techniques and discusses the results of simulation studies of powered belt conveyor networks. The performance of such networks depends on many factors. Although the directional effects of these factors seem intuitively apparent, quantitative estimation of their magnitude is very difficult. (One would need to derive expressions for the expected and maximum lengths of series queues with arbitrary arrival distributions.) Monte Carlo Simulation, using GPSS, has proved to be a useful tool for estimating these effects. This GPSS simulation model has been validated by comparing its output with the performance of an existing system.

SYSTEM DESCRIPTION

The networks of interest have several distinguishing features in common. (They will differ only in size and configuration.) First, they handle the cased output of packing lines. The cases may be of different sizes, and the distributions of their arrival rates to the network may be of any form. Second, the conveyors may each be run within specified speed ranges, depending primarily on questions of safety, damage to cases of product, and power required. Finally, all merges of case streams are two way merges. The merges are accomplished by mechanical gates (see figure 1) which allow cases to flow from only one of the two conveyors at a time. The action of the locking mechanism on the gate arms which span the conveyors is such that when either arm is moved from its rest position the opposite arm will be locked closed. This "opposite" arm will remain locked until the first one returns to its rest position. If gaps in either case stream are sufficiently small to prevent closing of the arm, the opposite one will remain locked indefinitely. Also note that cases will "use" a gate for a time which varies with their size.

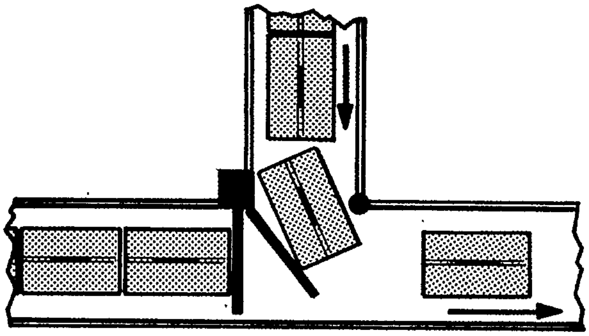
MODEL

Each of these network components must be described to the computer. The most difficult component to describe is the gate. (Conveyors may be described with ADVANCE and QUEUE or STORAGE blocks; arrival distributions with FUNCTION statements.) Table A is a reproduction of the basic coding necessary to describe a gate. More sophisticated coding is possible. The interest here is only to show how the basic communication may be accomplished. Notice that the two parallel sets of coding cross communicate, and the BUFFER block gives preferential treatment to those transactions waiting to use the side currently in use.

Sample Coding to Describe A Gate

	Side 1			Side 2	
	(Arriving Transactions)			(Arriving Transactions)	
	QUEUE	1		QUEUE	2
	TEST E	V1,K0		TEST E	V2,K0
1	VARIABLE	F1+X1	2	VARIABLE	F1+X2
	SEIZE	1		SEIZE	1
	DEPART	1		DEPART	2
	ADVANCE	10		ADVANCE	10
	RELEASE	1		RELEASE	1
	SAVEVALUE	2,K1		SAVEVALUE	1,K1
	BUFFER			BUFFER	
	SAVEVALUE	2,K0		SAVEVALUE	1,K0

TABLE A



Top View of a Gate Merge Intersection

FIGURE 1

DESIGN PROBLEM

To illustrate the use of this program, consider a hypothetical design proposal whose parameters and configuration are specified below.

Parameters

a) Line rates

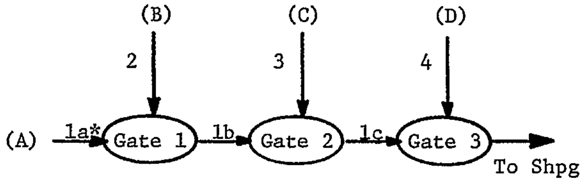
Line	Rate (cases/min.)
A	12 ± 3
B	20 ± 3
C	8 ± 1
D	12 ± 1

b) Proposed conveyor speeds and lengths

Conveyor Number	Length (feet)	Belt Speed (feet/min.)
1a	20	150
1b	30	150
1c	100	150
2	10	100
3	6	100
4	17	100

c) Case lengths are all 20" long.

Configuration



Design Questions

1. What are the maximum and average queues to be expected on conveyors 1, 2, 3, 4?
2. If conveyor 1 is increased in speed to 200 fpm, what effect will this have on buildups in the system?
3. With conveyor 1 running at 200 fpm, what will be the effect of a speed increase of 7 cases/min. on line C?

Table C shows summary statistics for cases 1--3. The statistics for case 1 show a steady buildup at the feeder side of the last gate. (i.e. The last line is unable to get a case on the conveyor because the stream side is too heavily loaded.) Statistics for cases 2 and 3 indicate both are stable and operable.

SUMMARY QUEUE STATISTICS FOR DESIGN PROBLEM

*Number of Cases

Conveyor Number	Case 1 Contents* Max.	Case 1 Contents* Avg.	Case 2 Contents* Max.	Case 2 Contents* Avg.	Case 3 Contents* Max.	Case 3 Contents* Avg.
1a	2	.53	2	.46	2	.44
2	2	.60	2	.41	2	.33
1b	6	1.27	3	.63	5	1.40
3	6	2.71	2	.47	3	.85
1c	2	.76	13	2.43	13	3.49
4	Increasing		10	4.86	9	3.61

TABLE C

Conclusions

There are several general conclusions that one can make from these results. First of all, in the case of either case rate increases or addition of new lines, system behavior "upstream" from the change should not be affected. (i.e. Buildups on conveyors 1a and 2 should not be affected by the speedup of line C unless cases back up on 1b and jam Gate 1.) It may thus prove economical of computer time to reduce the problem size by studying only the downstream portion. One might also consider the possibility of breaking the main conveyor into several smaller ones which run at different speeds. Second, note that increasing conveyor speed helps, but the effect is far from linear. Cases get through the gate faster, but they also arrive faster from upstream. The result is a redistribution of the queues. In general, one wants that conveyor speed which is just sufficient to clear the system. A simple calculation will show that even at this "optimum" setting, the conveyor is running much faster than theoretically necessary. At maximum rates on all lines, the main conveyor will be receiving 61 cases/min. which at 20"/case is roughly 102 ft./min. of cases, well below the actual conveyor speed of 200 ft./min. It is the action of the gates that causes this inefficient utilization of the conveyor. To make efficient use of the conveyor, it is desirable to process the cases in "slugs" of 2 or more. The natural action of the gates will tend to cause this type of flow, and once started it is self-feeding. Thus for a given conveyor speed, upstream gates will be inefficiently utilized and will inefficiently utilize the conveyor. Downstream gates will show higher utilization and will utilize the conveyor more efficiently. This behavior would lead one to believe that other gating policies are better than the passive switching of the mechanical gates. Investigations of this question are currently underway.

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*Conveyors 1a, 1b and 1c are each sections of the same conveyor.