A GENERALIZED SIMULATION MODEL OF AN AUTOMATED CART TRANSPORTATION SYSTEM

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ABSTRACT

The modern-day hospital is faced with the problem of transporting to their wards, operating rooms etc. supplies from a central supply department. The trend among large hospitals, currently under construction, is to automate this material handling system. Unfortunately, many of these systems are, through faulty design, incapable of delivering the supplies on schedule. This paper presents a general-purpose simulation to analyze critical portions of the automated system. Results of its application for a large 2000-bed medical complex are also presented.

1. Introduction

Hospitals with upwards of 1000 beds are becoming quite common.

A major problem in hospitals is transportation. Supplies (surgical instruments, food, linen, etc.) have to be shipped from supply points to specified destinations. Items, such as, soiled linen, empty trays, etc. have also to be returned for cleaning. This requires the hospital to be capable of handling a heavy traffic flow. A transportation system that is used is an automated conveyor system. This consists of an interconnected group of overhead powerflexes. The powerflexes are connected by shunt lines or free rails. Each powerflex consists of a series of pusher pendants. Carts are placed on the pusher pendants. The cart is then carried along the powerflex. When the cart arrives at the entrance of a shunt line it encounters a sensing device. This determines if the cart should proceed on the powerflex or enter the shunt line in order to arrive at its specified destination.

Once a cart enters a shunt line it is moved by gravity till it reaches a stop. The stop is encountered if there is another cart preceding it on the shunt line or, if it is in a position to enter the next powerflex. A sensing device on this powerflex determines if the next pusher pendant is empty. If so, the stop on the shunt line is released allowing the cart to enter the powerflex by hooking onto this pusher pendant.

Each shunt line has a maximum number of carts that can be on it at any given moment. If a cart wants to enter the line and is unable to because it is filled to capacity, it cycles. This implies that the cart is forced to continue along the powerflex. When it returns to the shunt line entrance at a future time it will enter unless the line is again filled to capacity. Thus, a cart may go through many cycles before it finally reaches its destination.

2. The System

The automated cart transportation system consists of a number of powerflexes connected by shunt lines. Each powerflex has pusher pendants which are used to carry carts. The spacing between pusher pendants are the same on a particular powerflex. However, they may differ between powerflexes. Speeds of each powerflex may also vary. Shunt lines are characterized by two parameters: i) the maximum number of carts that can be on the line at any given time ii) the time required for a cart to move from the entrance to the exit of the shunt line.

Pusher pendants and carts are characterized by their status. The former are either occupied by a cart or not. The latter have either entered the system or left it.

There are a number of points along the powerflex and shunt lines where a pusher pendant or cart may change its status. These points are referred to as nodes. Nodes are of four types: i) Entry nodes: Nodes at which carts can enter the system. These nodes exist either on powerflexes or at the entrance to a shunt line. ii) Exit nodes: Nodes at which carts leave the system. These nodes exist either on powerflexes or at the exit of a shunt line. iii) Shunt Entry nodes: Nodes at which there is an entrance to a shunt line. An occupied pusher pendant arriving at this node may leave it empty if the cart it carried was programmed to move down the shunt line. These nodes exist only at the intersection of a powerflex and shunt line. iv) Shunt Exit nodes: Nodes at which there is an exit from a shunt line. An empty pusher pendant arriving at this node may leave the node occupied by a car. This occurs when a cart is waiting in the shunt line for an empty pusher pendant. These nodes exist only at the intersection of a shunt line and powerflex.

Apart from being characterized by their type they are also identified by their distance from adjacent nodes along the powerflex. Distances in practice may range from 6 to 500 ft.

Another parameter of the system is the cycle time. When a cart cannot enter the shunt line it was programmed for because it was filled to capacity it cycles. The time taken by the pusher pendant to move once completely around the powerflex is defined as the cycle time.

The status of an automated cart transportation system is defined at any given moment by the status of each pusher pendant and shunt line in the system. The dynamics of the system can be expressed from one time unit to the next. Each pusher pendant would have moved a certain distance during this period. Otherwise, its status can change only if a pusher pendant passes a node. If this event does not occur the only change in status is the relative location of pusher pendants to nodes.

System capabilities are measured primarily in terms of the ability to (i) handle a specific loading schedule and (ii) transport items from supply point to destination in a "reasonable" span of time, that is, items arrive at their destination on schedule.

An entire hour of operation is simulated. Two standard forms and two optional forms of output are available.

The first standard form computes average utilizations of each shunt line and each powerflex section. The second standard form provides information regarding each type of cart loaded at a particular entry node and destined for a specific exit node. Numbers passing through the system average and maximum time spent in the system are computed.

The subroutine to obtain these figures also provides the self-verifying feature of the simulation. This program identifies each cart and traces it through the system. This is similar to manually verifying that each cart was indeed moved correctly through the powerflexes and shunt lines by the simulator.

Two forms of graphical options are available. The first provides utilization of any user-specified section or shunt line on a per minute basis. The second plots the number of user-specified type of cart that are in the system on a per minute basis.

3. The Application

The program was used by a manufacturer of automated cart systems in designing a system for a large (2200 bed) medical center in Germany. Their interest was two-fold: i) Determine if the designed system could handle the traffic load ii) Obtain a loading schedule that was practicable.

The entire system was spread over a half mile and numerous buildings. It would have been possible to analyze the whole system. This was not considered necessary.

Only a portion of the system was heavily loaded. This portion (consisting of 8 powerflexes and 18 shunt lines) handling all items going through the system was modelled.

Data regarding initial status of the system and loading schedule for the hour is then inputted to the model.

When a loading schedule is not feasible because of recycling the simulation indicates what adjustments can be made to the schedule so that it can be made feasible.

4. Conclusion

It is empirically evident, that a generalized simulation model of the automated cart transportation system is useful. The model described herein provides information regarding the behavior of the system quickly and cheaply considering the magnitude of the investment. Results for an hour (with an average loading schedule) were obtained in less than a minute on an IBM360/50. The self-verifying feature of the algorithm assures the user as to the accuracy of the results. Simulating an entire day would have a minimum cost of $200, additional costs being incurred according to the output options used.