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ANIMATED GRAPHIC SIMULATION OF AN AUTOMATIC GUIDED VEHICLE SYSTEM (AGVS)

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The graphic simulation package PCMODEL [1] is successfully applied to the planning of an automatic guided vehicle system (AGVS) in one of Intel's facility. The AGVS is controlled by one central computer and consists of a number of docks from which materials are either dropped or picked up by the AGV; the dispatch of AGV is prioritized to efficiently perform material handling. The utilization of AGV can be obtained through simulation, and is used to predict the number of AGV in the system. The AGV can carry two loads, therefore, it is poorly utilized if it only transports one load at a trip. To better utilize AGV, the control delay concept is introduced, which forces the AGV to carry as many as two loads as possible at each trip. The simulation also provides guideline on the selection of control delay.

INTRODUCTION

Intel commits itself to be the world class manufacturer and the leader of technology. In order to rapidly deliver high-quality products with low price to our customers, a highly automated factory was added to our manufacturing strength in 1984, at Arizona site. This factory employs state-of-the-art equipments including an automatic guided vehicle system (AGVS) for material handling. This paper is to report the planning process of the AGVS using animated simulation technique.

The automatic guided vehicle (AGV) is a computer-controlled, driverless vehicle [2]. The material to be delivered by AGV is contained in totes (or other containers), and an AGV will pick up or drop a tote on a dock. Since an automatic guided vehicle system may have many docks, complicate decision logics (such as priority), and a number of AGVs, it is difficult to plan a system without resorting to simulation. The simulation will provide the following insights:

(1) Design faults can be exposed and eliminated; for instance, a traffic bottleneck.
(2) The optimal number of AGVs and optimal size of docks can be determined.
(3) Design details can be explored.
(4) The system behavior can be studied with various assumed conditions.

However, it is cumbersome and time-consuming to perform a simulation using a general programming language such as Fortran; the coding may be lengthy even for a simple system; as a result, the debugging is difficult; worst of all, the efforts may not be transferrable from one application to another. The above drawbacks can be largely eliminated if a special simulation language is used. There are several special simulation languages that are available for an AGVS simulation: PCMODEL [1], GPSS [3], SIMAN [4], SIMSCRIPT II.5 [5], AUTOMOD [6], and SLAM-II [7].

A simulation language with animation feature is easier to program since the movement of entities can be observed and better managed; hidden bugs become obvious. The simulation results can be better conveyed to and accepted by the management. In this paper, PCMODEL [1], which is user-friendly and has good color-graphic animation, is applied in planning the AGVS.

SYSTEM DESCRIPTION

The factory where an AGVS is planned is an integrated circuit (IC) assembly facility which consists of the following sequential processes: wafer sawing, die attaching, wire bonding, molding, trimming and forming, lead soldering, and packing/shipping [8]. The principal input and output materials for each process are listed in Table 1.

Table 1: Input and Output Materials of Assembly Processes

Process	Input Material	Output Material
Wafer Sawing	Wafers	Scrap
Die Attaching	Lead Frame	None
Wire Bonding	Metal Wire	None
Molding	Molding Compound	Scrap
Trimming/Forming	None	Scrap
Lead Soldering	Tubes	None
Packing/Shipping	Empty Box	Finish product

The material handling is between inventory and manufacturing area; the required input materials are delivered from inventory while the output materials are shipped to inventory. The materials are contained in a tote with size 24"L by 16"W by 8"H and is transported by the AGV.

The AGV used is unidirectional with average speed 100 ft/min. Equipped with optical sensors, the AGV can recognize codes on the floor and follow a specified guidepath. On top of the AGV, there are two shuttle mechanisms, which are similar to robotic arms, and the AGV can load or unload two totes simultaneouly.

Two kinds of dock are utilized: pickup dock on which the AGV will pick up a tote, or drop dock from which the AGV will drop a tote. It should be noted that the AGV always deliver input materials (mold compounds, tubes, boxes) to the drop dock, and picks up output materials (scrap or finish product) from the pickup dock.

To facilitate just-in-time (JIT) material handling, a sensor is embedded in each dock, and is hardwired to the central computer; therefore, the status of each dock is continuously monitored by the central computer. When an operator removes or deposits a tote on a dock, the sensor will be triggered, which signifies a request; the central computer will be notified and will schedule the dispatch of the AGV. The dispatch of AGV is based on priority associated with each dock. The priority is based on the cycle time which is the time a tote of material is used up or created; therefore, the shorter the cycle time of a dock, the higher the priority of the dock is. Once determined which docks are to be served, the central computer will relay the destination and tasks (loading or unloading) information to the AGV through an modulated infrared (IR) device at selected locations. Upon receiving information, the AGV will automatically execute the assignment. The communication will resume when the AGV has fulfilled the assignment and returned the communication point. It is interesting to note that the mission of an AGV is opposite to what the operator does, i.e. the tasks of the AGV is to either fill a dock that was emptied by the operator, or empty a dock that was filled by the operator. If designed properly, the pickup docks will always be empty while the drop docks will always be full. As a result, material accumulation or shortage can be minimized; Since the material handling is purely based on demand; this AGVS is a Kanban system [9].

ANIMATED GRAPHIC SIMULATION

The simplified layout of the facility with the location of docks and the guidepath of the AGV is shown in Figure 1. Variables of interest are shown at the upper left corner of the Figure 1, which are: AGV utilization (%), AGV status (number of totes the AGV is carrying), type and priority of each dock, and the status of each dock (number of requests to be served). The average waiting time or the elapse time of each dock from initiating a request to being served by the AGV, can also be displayed [1].

Currently, the AGVS is limited to molding, trimming/forming, lead soldering, and packing/shipping processes. Dock 1-9 (Figure 1) are located in the manufacturing area while 10-14 are in the inventory. Dock 1,4,6,9,10 are drop dock, and docks 2,3,5,7,8,11-14 are pickup dock. It is noted that each dock in manufacturing area accommodates one tote, while each inventory dock is designed to have two hour materials in queue. If requested by a drop dock (1,4,6,9), the AGV will first go to one of the inventory docks (11-14) to pick up the requested materials (in a tote); then, it will travel to the requesting dock and drop the tote. However, if requested by one of the pickup docks (2,3,5,7,8), the AGV will travel to the dock directly, pick up the tote, return to inventory and drop it on dock 10. The material, type, and associated process of each dock are listed in Table 2.

Table 2 Material, Type, and Process of Each Dock

Dock	Type	Process	Material
1	Drop	Soldering	Tube *
2	Pickup	Soldering	Empty Tote
3	Pickup	Mold A	Scrap **
4	Drop	Mold A	Compound A
5	Pickup	Mold B	Scrap
6	Drop	Mold B	Compound B
7	Pickup	Trim/Form	Scrap
8	Pickup	Packing/Shipping	Finish Product
9	Drop	Packing/Shipping	Empty Box
10	Drop	Not Available	Output Materials
11	Pickup	Sustain Dock 4	Compound A
12	Pickup	Sustain Dock 6	Compound B
13	Pickup	Sustain Dock 9	Empty Box
14	Pickup	Sustain Dock 1	Tube

*: Totes are brought in by the AGV.
**: Two molding processes are used; each requires different molding compounds.

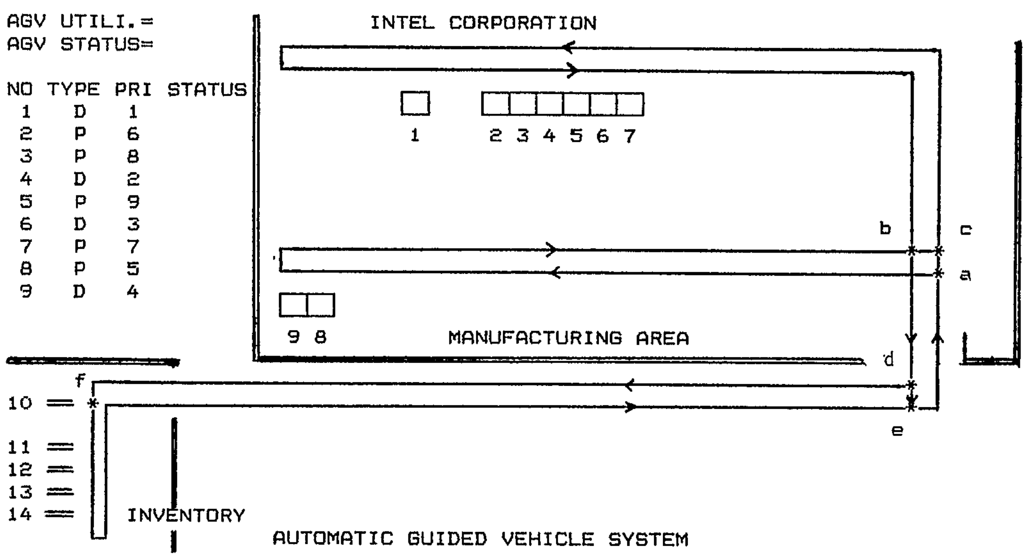

Figure 1: Layout with Dock Location and AGV Guidepath

The central computer must frequently communicate with the AGV so that material handling can be readily performed. There are two such communication points in the system as shown at point d and f in Figure 1. Point f is the "home" position of the AGV, i.e. if there is no request, the AGV will always park at point f. The communication point d is designed to improve the efficiency of the AGV. With a communication point at d, the AGV can receive instructions halfway to eliminate unnecessary traveling time.

There are five branch points (a,b,c,d,e in Figure 1) where the AGV may turn.

Point a:
When arrived at point a (AGV moving upward), the AGV may turn left to dock 8 or 9.

Points b,c,d:
when arrived at point b (AGV moving to the right), the AGV may travel to point c and move upward to dock 1-7; or it may travel to point d to leave the manufacturing area.

Point e:
When arrived at the communication point d (AGV moving downward) the AGV may either travel to inventory or to point e to return to the manufacturing area.

The number of AGV can be predicted from the utilization of AGV obtained in simulation. Initially, one AGV is assumed; if the utilization of the AGV in the simulation is high, more AGVs may be added to the system. This practice is repeated until the utilization of each AGV is acceptable.

The type, cycle time and priority of docks in manufacturing area are listed in Table 3:

Table 3: Type, Cycle time and priority of Docks

Dock	Type	Cycle Time (Minute)	Priority
1	Drop	22	1
2	Pickup	65	6
3	Pickup	80	8
4	Drop	42	2
5	pickup	80	9
6	Drop	42	3
7	Pickup	72	7
8	Pickup	54	5
9	Drop	54	4

The specification of the AGV is listed below:

Initial condition: One AGV is used
Speed = 100 ft/minute
loading or unloading time = 30 seconds

It is noted that the priority is based on the cycle time of each dock. To simulate the randomness of production, the cycle time of each dock is a uniform-distributed random variable whose upper and lower limits are 10% off the value indicated in Table 3. Also, the AGV will randomly stop and resume motion after 5 seconds to simulate human interference.

Simulation Results

At the end of 8 hour simulation, it is found that the utilization of the AGV is 82%, therefore, one AGV is able to perform material handling in this application.

The AGV can carry two totes, therefore, if it responds to only one request, 50% capacity is wasted. If each AGV can be efficiently utilized, the number of AGV in a system may be reduced and results in significant capital saving. To better utilize the AGV, the following logics may be taken: upon receiving a request, the AGV will not be dispatched unless one of the following conditions is satisfied:

(1) Another request occurs.
(2) The AGV has waited for a specified time or called control delay.

It is noted that the above control logics are to "force" the AGV to carry as many as two totes as possible at each trip. As a result, the utilization of AGV under the same manufacturing conditions will decrease as shown in Figure 2. It is observed that the AGV utilization can be reduced to 70% if the control delay is longer than 5 minutes.

The impact of control delay can be revealed from the balance index of each dock, which is defined as follows:

$$\text{Balance Index} = \frac{\text{Average Waiting Time}}{\text{Cycle Time}}$$

the waiting time of a dock is the elapse time from initiating a request to being served by the AGV, and can be displayed by the utility of PCMODEL [1].

The balance index is an indicator of balance of material flow. If the waiting time is less than the cycle time, or balance index is less than one, the flow is balanced and material shortage or accumulation may not occur. The balance index of each dock with control delay is shown in Table 4.

Table 4: Balance Index of Each Dock

Dock	No Control Delay	5 Minutes Control Delay
1	0.27	0.51
2	0.05	0.073
3	0.067	0.071
4	0.14	0.16
5	0.05	0.06
6	0.02	0.02
7	0.06	0.066
8	0.068	0.077
9	0.16	0.17

From Table 4, it can be observed that the control delay introduced will increase the balance index of each dock, which implies that each dock will have to wait longer for the AGV. Therefore, there is tradeoff between improving AGV efficiency and speedy material handling. From Figure 2, it is found that longer control delay will not improve the AGV efficiency significantly; thus, the optimal choise of control delay is 5 minutes.

CONCLUSION

In this paper, the planning an AGVS in one Intel's facility was presented. The number of AGV is successfully predicted using the animated graphic simulation package called PCMODEL [1].

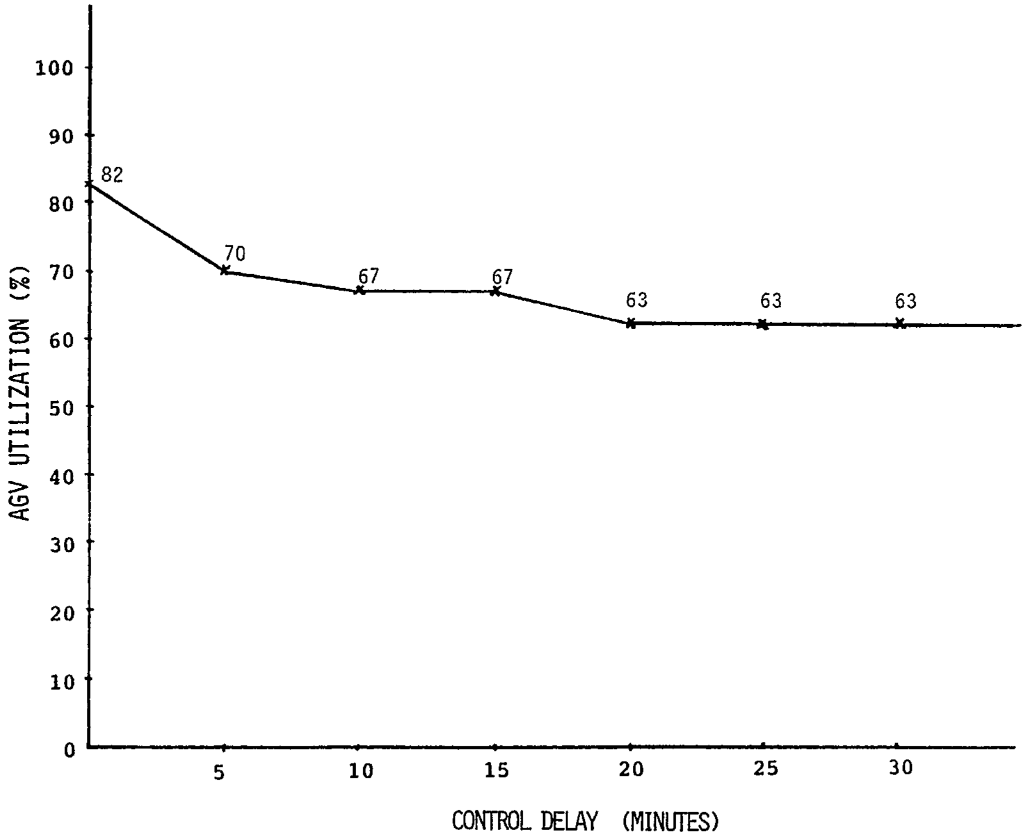

Figure 2: AGV Utilization vs Control Delay

The number of AGV was deduced from the utilization of AGV in a system. In the simulation, one AGV was used; it was shown that the utilization of the AGV was 82%, therefore, one AGV can perform material handling in this facility.

The AGV has two tote capacity, and 50% capcity will be wasted if it only carries one tote at each trip. The control delay concept was proposed, which is designed to force the AGV to carry as many as two totes as possible at each trip. It was shown that by introducing 5 minute control delay, the AGV uitlization drops to 70%.

Althogh the AGV can be efficiently utilized with a control delay, the control delay may increase the waiting time that each dock has to wait for the service of AGV. From the simulation, the optimal control delay was identified to be 5 minutes.

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