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CIMS 에서의 규칙에 근거한 AGV 경로의 설계

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Rule-Based Approach for the Design of AGV Path in CIMS

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ABSTRACT

Implementation of AGVS (Automated Guided Vehicle System) in CIMS (Computer Integrated Manufacturing System) generally requires substantial study to optimize design and performance of the guide path. Traditional mathematical approaches have been used with limited success to analyze AGVS.

These approaches, however, do not provide a pratical opportunity to use by path designers. This paper presents a new approach based on rules in designing and assessing AGV path to have better design of the closed-loop layout. A framework for the approach is proposed and a case study is reported to demonstrate the framework. Deletion of seldom used paths and addition of bypasses to solve the congestion problem are conducted automatically through simulation experiments. To visualize the results a graphic control program is developed and integrated with AutoMod/AutoGram simulation package.

1. Introduction

Material Handling Systems (MHSs) have been called the "key to integration in manufacturing". A flexible manufacturing system usually consists of a set of manufacturing cells, and an MHS controlled by computers interfacing with them. Elimination of the human interference from material transport within the manufacturing environment and warehousing has been made possible by developments in guided-vehicle technology, i.e., AGVSs. Despite the various problems associated with the installation and maintenance of an AGVS, applications are widespread in the areas of warehousing, assembly, and distribution.

The designer of an MHS using AGVs must address the following issues [5]:
[a]. the number of vehicles required;
[b]. the layout of the AGV guide-path;
[c]. the traffic flow control pattern;
[d]. decisions regarding provisions of control zones and type, number and capacity of buffer for the vehicles;
[e]. vehicle dispatching rule.

In order to handle these issues, there have been two general approaches - the analytical approach and the computer-simulation approach. The former has been usually confined to finding the number of necessary AGVs, the direction of the AGV guide-paths, and the load P/D (pick-up/drop-off) point locations. However, this approach has many drawbacks. First, it does not consider AGV congestion, vehicle interference, collision, and blocking problems, but only consider the total distance traveled. Second, this approach can produce very large problems, due to integer-programming characteristics. Thus, complex real-world cases can not be solved. Third, it fails to consider dynamic characteristics of an AGV such as acceleration/deceleration.

On the other hand, the computer-simulation approach has overcome the drawbacks of the analytical approach. When designing an AGV layout, manual calculation leads to uncertainty when estimating the system capacity. Considerations must be given to many factors such as AGV speed, load transfer times, variations in material flow, available floor space, etc.. Calculating these factors manually will be too complex, which will mean that simplifying assumptions have to be made. As a result of this, the system capacity will usually turn out to be either too large or too small when the system is finally installed. Of the techniques used to design an MHS, simulation is probably the most versatile and widely applicable technique. Simulation provides the facility to build a model of the system and actually run it during the design stage of a project. It gives opportunities to test numerous versions and observe the effect on the system, for different sets of parameters. But it should be pointed out that the simulation itself does not design the system. When a design exists, simulation can test it and see how efficient the design is against the requirements.

According to Norman [6], about 15 % of the performance loss in an AGVS is caused by faulty partitioning of the guide path. Industrial practitioners have complained that, even though simulation approaches are used, there are no rules or systematic procedures to follow when modifications of the designed guide-path are needed.

In this study, AutoMod/AutoGram simulation package [7] is used to build a model of the desired MHS. AutoGram acts as both a pre- and a post-processor on the AutoMod code. A system can be programmed entirely in AutoMod if desired; AutoMod will stand alone, although there will be no animation. Creating a movement system in AutoGram creates AutoMod code automatically; it also generates some special files that allow easy animation.

2. Design of an AGV Guide-Path Layout

The AGV guide-path layout problem was first formulated by Gaskins and Tanchoco [1] as a zero-one integer programming problem. The problem is formulated as a node-arc network where the nodes represent P/D stations, and aisle intersections, and the arc are guide-paths which connect the nodes. The objective function for this formulation is the minimization of total transportation distance, i.e, flow volume times distance. Gaskins and Tanchoco [2] addressed the problem of defining flow paths for free-ranging vehicles. A model is presented whereby the number of allowable flow paths and the flow direction between nodes (P/D and intersections) of the layout network are determined. Kaspi and Tanchoco [4] describe an alternative formulations of the AGV flow path layout problem based on a branch-and-bound technique. Goetz and Egbelu [3] addressed the problem of selecting the guide path as well as the location of P/D points for outward bound and inward bounds parts to departments. They solved it as a linear integer program, with the objective of minimizing the total distance traveled. But, load P/D points are usually determined by other environmental material systems, such as AS/RS or conveyors. So, P/D points usually can not be altered. Sharp and Liu [8] present an analytical method for configuring the network of a fixed path, closed-loop MHSs. Their purpose is to make good initial decisions with respect to adding shortcuts (cutbacks), adding off-line spurs, and their lengths, so that, of the thousands or millions of possible network configuration, only a very small number need be examined by simulation. They minimize the sum of load-carrier costs and spur costs in the flow network by using a general purpose integer programming algorithm.

In these analytical methods, there is no considering of blocking or congestion problems, only total distance traveled is considered. Sometimes, it is more important to minimize max-congestion. When all P/D points are in close proximity, traffic can adversely affect productivity because of blocking points and control points.

2.1 Problem Description

In the researches of AGV guide-path layout, they assumed that an initial set of bidirectional paths is given, and then they find the optimum unidirectional flow by an integer linear programming approach. The given layout itself is never altered. Basically, there is no decisive decision tool for the effective design of AGV guide-path layout.

The main function of this system is the generation of new guide-path so as to avoid congestion and blocking problems by a rule-based approach, and the deletion of the segment or the control point which are not used. A control point can be considered as physical sensor at which vehicles can wait or stop. A segment is a portion of the guide-path. So an AGV path designer, with the help of this system, will accomplish all his work - run a simulation model, output analysis, and path improvement.

2.2 Assumptions

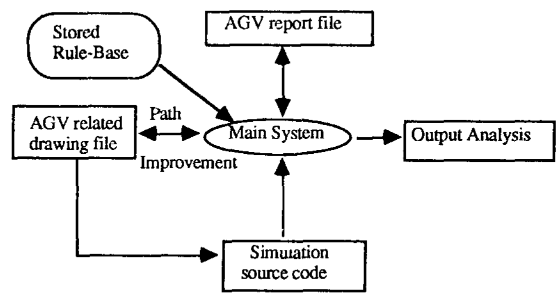
To tackle AGV guide-path layout effectively, we will make the following assumptions.

[a]. AGV path configuration is the closed-loop type.
[b]. AGV path type is unidirectional.
[c]. The distance between two control points is greater than the length of an AGV.
[d]. New path could be generated interior bound of the main closed-loop.
[e]. If no reserve rule produces a solution, then there is nothing to add or delete new guide-paths.
[f]. Initial guide-path layout is given.

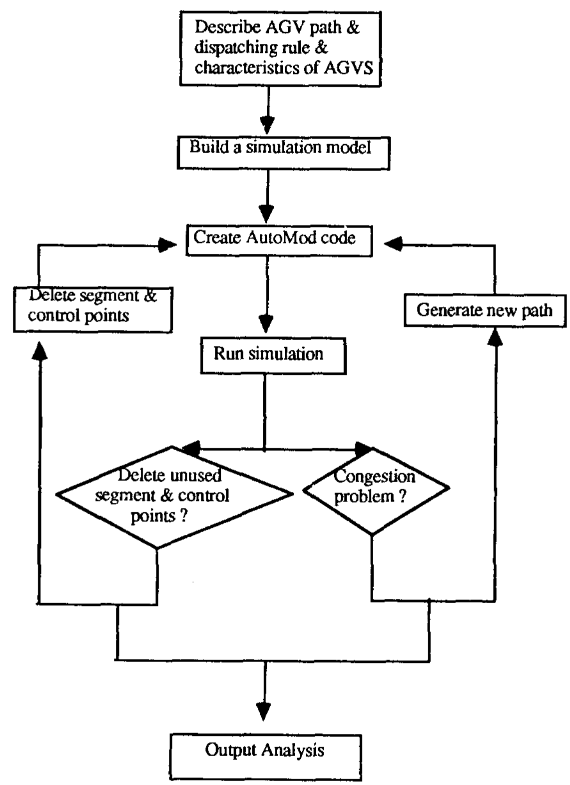
2.3 A Framework for Rule-based Approach

As shown in [Figure 1], the core main system is at the center of the overall AGVS, and communicates information to and from the simulation results statistics or the AGV layout drawing files. First, from the simulation result, the system investigates what problems exist in the AGV path layout, and then improves AGV path design. If a user wants the information about the path layout, then system supports a brief output analysis.

Basic procedure of this system is shown in [Figure 2]. Stopping rule applies either when the overall requirement (throughput) is satisfied or there is no path improvement due to the exhaustion of the stored rules.



[Figure 1] System Structure of the Rule-based Approach



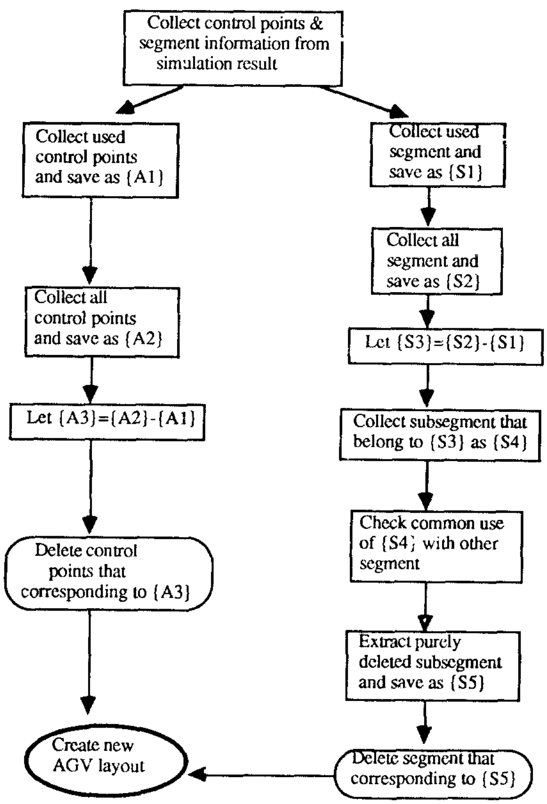
[Figure 2] Sequence diagram

2.4 Deletion of guide-paths & control points

This procedure is independent of AGV path, but simulation time must be sufficient to cover overall material movement. Otherwise, this system may delete useful guide path or control points. It is not easy and time consuming for a designer to delete segment or control points from simulation result. This system provides a new automatic method to delete unused control points and segment, so as to save costs involving AGV layout installation and to check initial design error in advance.

From control point statistics, we can get the utilization of each control point. If layout problem is not serious , then all utilizations are small. Otherwise, some points are very small, and the others are very high. Thus, those of high utilizations are considered. Two control points constitute one segment, and one segment constitutes of one or more sub-segment. So a certain sub-segment may be contained in another segment. From AGVS report file, we can get information about segment statistics. From this information, we extract the unused segments.

When a certain segment was unused, which must be deleted, we should be careful not to delete a sub-segment contained in other segment which is used. Otherwise, we commit the errors of deleting a sub-segment which must not be deleted. The problem solving procedure is summarized in [Figure 3].



[Figure 3] Deletion algorithm of control points & segment

2.5 Generation of new guide-paths to avoid congestion

In this procedure, we search the most congested segment from AGV result file, deduce overall AGV layout configuration, search the neighboring main segment with respect to original congested segment to link bypass, check whether bypasses exist, and then make a decision whether a new guide-path is necessary.

When a congestion or blocking problem appears, it is necessary to revise AGV guide-path in order to avoid it. To accomplish this, we must figure out the overall AGV guide-path type, the direction of the guide-path, and the existence of bypasses around a certain segment. By making rules about AGV guide-path direction and about the searching condition of the neighboring segment with respect to one determined segment, we can deduce what kind of new bypasses are necessary. If they did not exist in the appropriate location, we can add a new bypass into the original guide-path.

2.5.1 Decision Rules

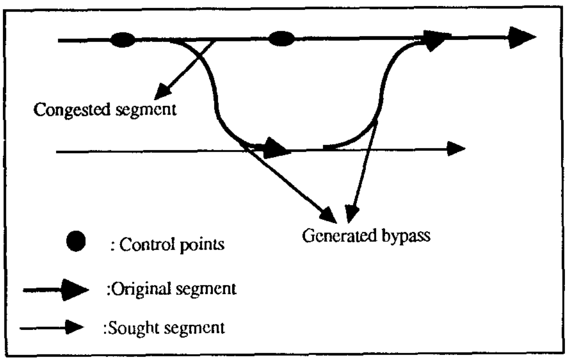
First, we must check whether the overall AGV path layout is clockwise or counter-clockwise. Second, we must deduce the relative location and the direction of two control points. The relative location applies when two control points are at the same axis-same level or at the same axis-different level. Third, we extract new main segment with respect to original segment by stored rule base. Basically, the rule base consists of 12 main rules. Each main rule consists of two to four sub-rules according to the direction of new segment and the relative location of the two control points. And in each sub-rules, we check the existence of one or two neighboring bypass. The first eight main rule apply when the axis of the congested segment is at the same axis-same level, that is to say, the congested segment is vertical or horizontal. [Table 1] shows these eight rules. For each eight main rule, two

[Table 1] Eight main rules (same axis- same level) out of twelve rules

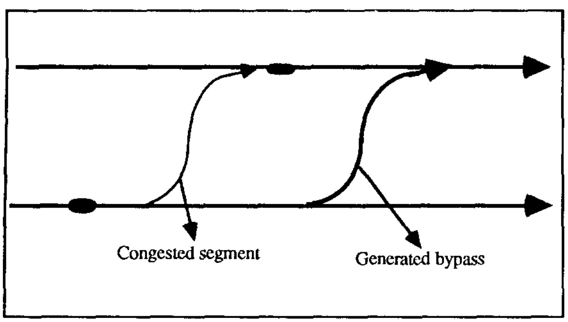
Rule number	Location of start point	Location of end point	Direction of segment	Overall path configuration	Sought segment
1	X-axis	X-axis	Left -> Right	CW (clockwise)	Below
2	X-axis	X-axis	Left -> Right	CCW(count clockwise)	Above
3	Y-axis	Y-axis	Down-> Up	CW	Right
4	Y-axis	Y-axis	Down-> Up	CCW	Left
5	X-axis	X-axis	Right -> Left	CW	Above
6	X-axis	X-axis	Right -> Left	CCW	Below
7	Y-axis	Y-axis	Up -> Down	CW	Left
8	Y-axis	Y-axis	Up-> Down	CCW	Right

kinds of sub-rule are established according to the direction (same or different) of two segment. In these cases, there are two alternatives to generate new guide-path. [Figure 4] shows one of those rule. The remaining four main rule apply when the axis of the congested segment is at the same axis-different level, that is to say, the congested segment is contained in two parallel main segments. For four main rule, four kinds of sub-rule are established according to the direction (same or different) of two segment and location (X-axis or Y-axis) of two control points. In these cases, there is one scheme to generate new guide-path to avoid congestion problem. [Figure 5] shows one of those rule.

When adding a new guide-path, it must be located within the boundary of original and new segments. A new guide-path (bypass) could be composed of only a curve, or a combination of curve and straight line according to radius value.



[Figure 4] Generation of bypasses in rule-1

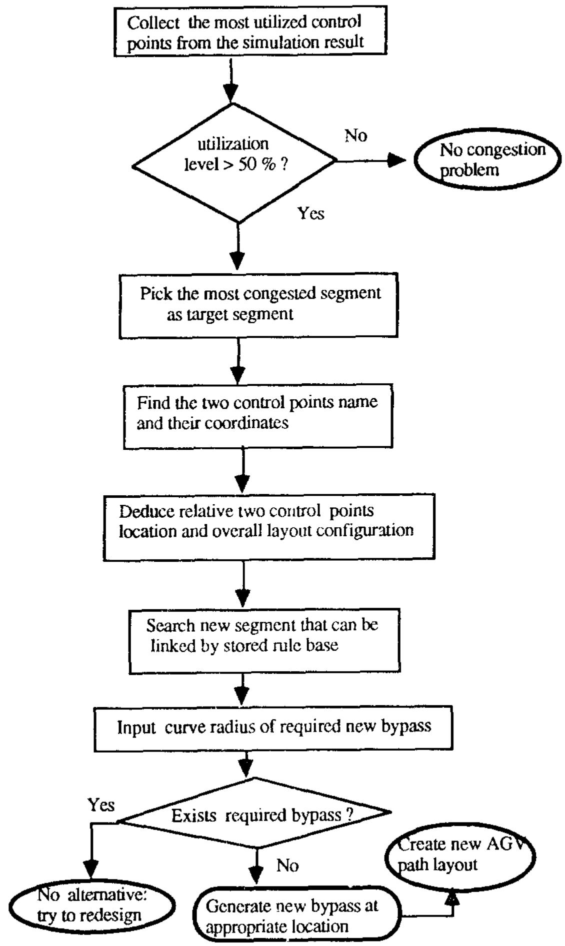


[Figure 5] Generation of bypass in rule-9

2.5.2 Generating Procedure

The utilization of control points is used as a criterion for congestion degree. So if the maximum utilization is beyond 50 %, then we can conclude that congestion problem exists in this system. Otherwise, we conclude that currently there is no congestion problem in this layout and simulation time. Here, the utilization of a control point represents the percentage of total simulation time during which the control point was claimed. If this is large for a certain point, then we suspect excessive vehicle congestion at this point. When all control points have low utilization, but the system can not digest total throughput, then it is recommended to increase the number of vehicles to carry out all requirements.

From AGV report file and AGV drawing file, the most congested segment location, and the length between original segment and new searched segment are obtained. A new added segment can only require a curve or a curve and a straight line. This is determined by the user input of radius length. The whole procedure is conducted interactively and iteratively and explained in [Figure 6].

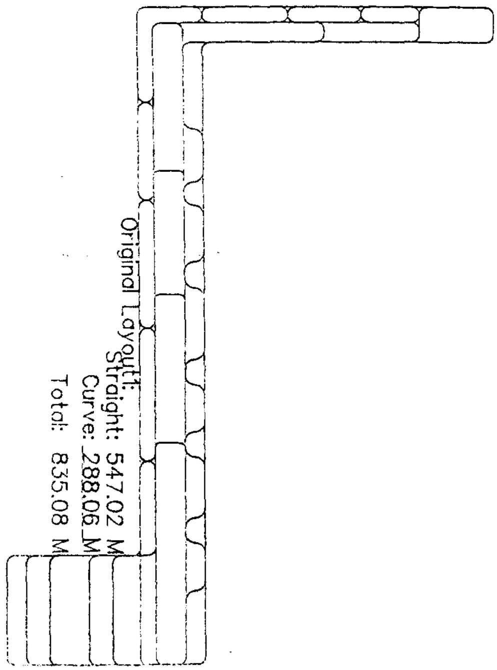


[Figure 6] Genetarion algorithm of new guide-path

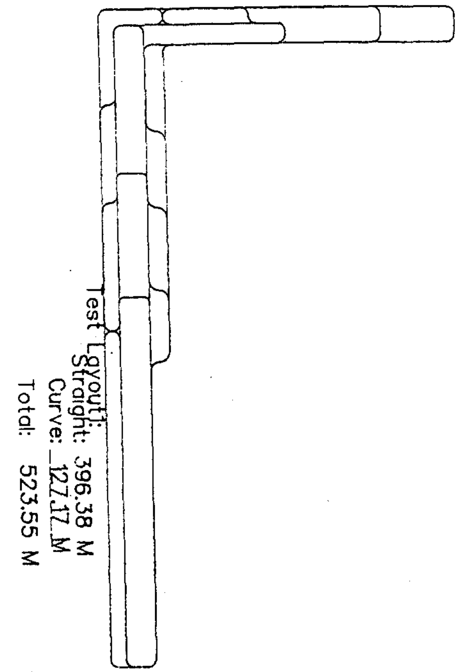
3. Application

This system was tested on a real world MHS, composed of an AGVS, AS/RS , and conveyor system. The original layout is shown in [Figure 7]. In [Figure 7], there is AS/RS at the upper part of the AGV layout. At the left and below part of the AGV layout, there are conveyors and other facilities. The overall direction of AGV guide-path is counter-clockwise. Other input parameters are as follows:

[a]. Input load
There are two kinds of load, one is created every 230 sec and the other is every 238 sec in succession. They are entered into the system for all day (24 hours) and the retrieval time from the system is confined to for eight hours a day.



[Figure 7] Original AGV layout



[Figure 8] Tested AGV layout

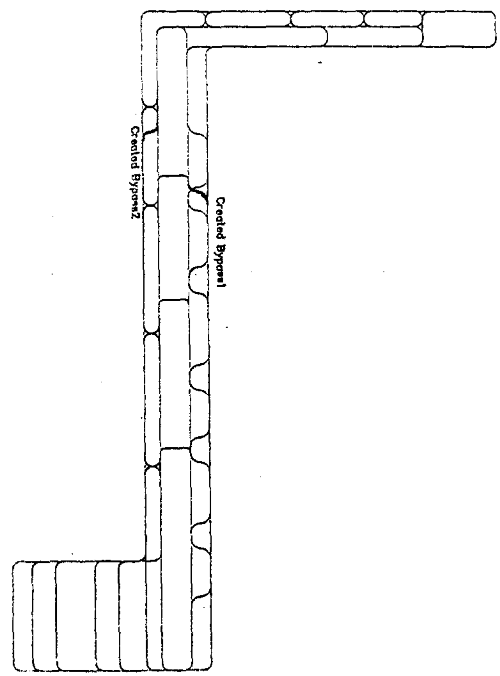
[b]. AGVS parameters
Curve speed is defined as 70 % compared to the straight line speed. Idle vehicle is dispatched to the load which has the largest waiting time. Seven vehicles are used. The speed, the acceleration, and the deceleration of each vehicle is 1 m/sec, 0.8 m/sec(2), and 0.4 m/sec(2), respectively. The pick up time is 11 sec and drop-off time is also 11 sec.

[c]. AS/RS parameters
Seven machines are used and the type of machine is double. The unit rack dimension is 1.52 m (width) * 1.61 m (length) * 2 m (height). Total location are 52 (bay) * 14 (row) * 7 (tier) = 5096 (cells). The horizontal velocity and acceleration of machine 1.33 m/sec and 0.3 m/sec(2), respectively. The vertical velocity and acceleration of each machine is 0.25 m/sec and 0.2 m/sec(2), respectively. The shuttle time is 17 sec.

[d]. Conveyor parameters
The speed of conveyor transfer is 0.17 m/sec.

The original layout was tested by deleting seldom used segments and control points. The result is shown in [Figure 8]. Even though this modification is made, the overall performance of the MHS is not changed.

In order to resolve the congestion problem, generation of new guide-paths was attempted. The result is shown in [Figure 9]. In [Figure 9], the newly generated guide-paths are marked with thick lines. Comparing the original and new layout, the average time / trip for AGVs is down from 933 sec to 760 sec, 19 % improvement is achieved.



[Figure 9] Generated new guide-path layout

4. Conclusions

Through this research, the more effective guide-path design system of an AGVS was attempted. Some improvement was made in the proposed system:

1) With the help of the automatic deletion algorithm, a designer could save his time and efforts in designing and assessing the closed-loop layout of an AGVS guide-path.

2) By using the automatic generation algorithm, congestion problem in an AGVS could be resolved. But this routine cannot solve a persistent congestion problem when decision rules are exhausted or successive congestion problems occurr in a certain segment, or the capacity of environmental facility is so small that it cannot handle the loads. Even though these cases are occured, it is still possible for a designer to redesign his layout by looking at a display of the most congested locations.

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