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MODELING AGV SYSTEMS IN MATERIAL HANDLING USED OF LOOP BASED

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ABSTRACT

In this paper a new architecture and control strategy of an AGV is proposed. It is organized as follows. The study objectives are to 1) provide information regarding the use and benefits of Automated Guided Vehicle (AGV) systems in manufacturing environments, and 2) review the literature related to design, modelling and simulation of AGV systems. A simulation model is built to study the performance of this controller.

- **KEYWORDS:** material handling system, AGV system. Simulation software, Flexible manufacturing system;

INTRODUCTION

Automate Guided Vehicles (AGV) has been applied for the flexible manufacturing system. Many factories were adopted it into assembly line or production line such as automobile, food processing, wood working, and other factories. Many researchers developed and designed in order to suite with their applications which are related to the main problem of factory.

Automated Guided Vehicle (AGV) Systems

AGV systems are mainly used for distribution of materials in warehouse environments, and movement of material to and from production areas and storage areas in manufacturing facilities. The first Automated Guided Vehicle. (AGV) application was for transporting groceries in a warehouse (Hammond, 1986). According to statistics in 1989 (Gould, 1990), AGV system installations with respect to their application types were profiled as following: JIT delivery systems (56%), FMS/FAS transfer system (13%), storage load transfer, non-AS/RS (12%), AS/RS interface (8%), progressive assembly (7%), mini-load AS/RS interface (1%), and others (3%). Some other applications of AGV systems in non-manufacturing environments include, but are not limited to, delivering mail, messages, and packages in offices, and delivering meals and laundry in hospitals.

In current AGV systems, the automatic guided vehicles move through the facility along predetermined paths (van dam et. al. 2004). However, with the increasing computing power available for onboard use, it becomes possible to determine AGV trajectories more frequently.

Basic Vehicle Types

Types of AGVs can be categorized as towing vehicles, pallet trucks, and unit-load carriers. Towing vehicles pull a series of trailers that are attached to the vehicle. The trailers are attached to and detached from the vehicle manually at the stations. The vehicle does not have lifting capabilities for a transfer mechanism. It can be used for any type of load. Pallet trucks are used for palletized loads and can have high lifting capabilities. They can pick up and deposit loads at the floor level. Unit load carrier may carry single or multiple loads on their deck. Some are capable of travelling sideways. The transfer mechanism of the carrier can be either an active or passive conveyor, such as a roller, belt, or chain conveyor, or it may be a lift/lower deck.

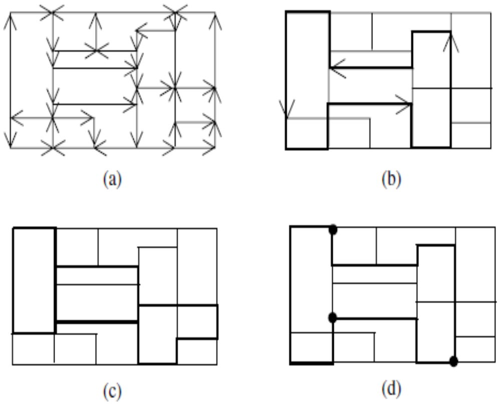
AGVs can be used in two different ways (Hammond, 1986). The first approach is to attach a work piece to the AGV having all manufacturing processes done while the AGV carries the work piece from station to station. In this approach, the AGV is freed only after all the processes for the work piece are completed. The second approach is to use vehicles only for moving the work pieces from one station to another. Vehicle is assigned to the work piece only for a single trip. In the former, number of vehicles required is significantly greater than in a normal AGV system. General Motors Company is the pioneer of such an assembly system built in the U.S. with 185 unit-load carriers.

Facility design

2.1Sequencing stations

An important problem when designing loop transportation systems is to determine the relative order of stations on a unidirectional loop, given a predicted from-to chart showing the material flow between stations, in order to minimize transportation cost. More precisely, all material unit loads are assumed to enter and leave the system through a specialized station 0. The objective is to minimize the total material flow through station 0, measured by the total number of unit loads.

Afentakis (1989) provides a direct formulation to the SSP but solves the problem heuristically by means of an interchange procedure. Dominance relations are developed by Kouvelis and Kim (1992). These help reduce the solution space and enable the authors to develop quick heuristics based on a decomposition procedure, and a branch-and-bound algorithm capable of solving instances of size 12. Kiran and Karabati (1993) have independently proposed dominance relations. In addition, they have identified a polynomially solvable case of the SSP and developed approximate solution procedures as well as an exact enumerative algorithm. The largest instance size attained by these authors is also 12. Using graph theory arguments, Leung (1992) develops a heuristic to sequence the stations starting with the solution obtained by means of the LP-relaxation of the problem.



Four basic material flow configurations: (a) conventional unidirectional network, (b) unidirectional loop network, (c) tandem configuration, (d) segmented loop topology

4.2. Blocking and collision avoidance

Given a dual track bidirectional loop formed by two single track unidirectional loops, one in each direction, and a set of interconnections to switch from one track to the other, there are several control problems to be addressed: (a) dispatching: assigning tasks to vehicles; (b) routing: determining an origin/ destination route for the assigned task; (c) scheduling: determining the timing of the arrival and departure of each vehicle in each zone. Langevin et al. (1996) have developed an integrated model for these three operational problems on a double track bidirectional loop. The material handling network is defined as a set of P, D, and switching nodes, and the set of the edges connecting them. Conflict is defined as occupancy or claim of a node or of an edge by more than one vehicle. The objective function is to minimize the completion time of all tasks by a given fleet size of vehicles. The authors use dynamic programming to obtain the optimal solution for two vehicles and propose heuristics for more vehicles. Desaulniers et al. (2003) have developed an exact method for the same problem. They use a heuristic to obtain an initial solution, a column generation, and a branch and bound solution procedure to solve the problem optimally for up to four vehicles. Given a unidirectional loop and a set of fixed stations on it, Ho (2000) uses simulated annealing to develop a dynamic zone strategy to partition the loop into a loop based segmented flow topology. A pair of zone adjustment and zone assignment procedures is also developed. The zone adjustment procedure redefines the zones as the vehicles complete some tasks over a working period. The zone assignment procedure allows the vehicles in adjacent zones to help each others.

Material handling system design

Tandem configurations were conceptualized by Bozer and Srinivasan (1989). Their 1991 article describes a heuristic based on the generation of a set of promising loops and the selection of an optimal subset by means of a set partitioning algorithm. Mahadevan and Narendran (1992) define a concept referred to as single vehicle loop layout which is a design similar to tandem configuration. They address the key issues in design and operations of such a configuration in an FMS. Bozer and Srinivasan (1992) compare the performance of tandem and conventional configurations and show that as the required number of AGVs increases, tandem performs better than conventional. Occena and Yakota (1991, 1993) examine operational policies in a tandem configuration and conclude that the tandem configuration could be easily implemented in an FMS. Choi et al. (1994) have developed a simulation model to compare single loop and tandem configurations. The single loop produces a shorter travel time and idle time, but tandem configurations result in a higher job completion rate. Lin et al. (1994) have measured the impact of load routing on the performance of a tandem configuration. Using simulations, Bischak and Stevens (1995) have shown that the tandem system has a higher expected travel time per load than a conventional configuration. This is due to the extra time required for transhipment across loops. Ross et al. (1996) have compared the conventional configuration, the tandem configuration, and a tandem configuration enhanced with an internal loop. The key performance measures were utilization, mean flow time, tardiness, and percent tardy. They conclude that tandem configuration matches the performance of conventional configuration, while it provides ease of control. Huang (1997) has developed a two stage optimization model for rehandling reduction in a tandem configuration. The main idea is to minimize the total number of transfer points, and to assign the loop to loop transfers to AGVs not operating in the tandem loops.

In the first stage, an integer programming model designs a single transfer point for each tandem loop. In the second stage, a network to connect the transfer points is designed using a minimum spanning tree.

4.3. Multi load AGV on a single loop

While unit load AGVs still represent the single largest segment of the AGV markets, some authors have examined the case of multiple load AGVs operating on a single loop. Sinriech and Palni (1998) propose an exact formulation for scheduling of multiple load vehicles over a finite planning horizon. Two heuristics are developed to handle larger problems. The performance of these heuristics which require perfect knowledge on a certain number of future periods are compared with the simple first encountered, first served dispatching policy. Liu and Hung (2001) consider a single AGV with two load capacity operating on a bidirectional loop. They develop rule based control policies to avoid deadlock of the vehicle in front of finite queue capacity of the P/D stations. The essence of rule based heuristics is to avoid circular wait states caused by inappropriate flow of jobs. The procedure does not always yield an optimal solution and needs full real time information on the shop floor. Sinriech and Kotlarski (2002) describe a scheduling algorithm for the operation of a fleet of vehicles carrying more than one load along a single loop. A state based scheduling algorithm is developed. The impact of increasing the vehicle capacity is evaluated based on variables such as cycle time, work in progress, and utilization.

4.4. Other operational issues

A number of other operational problems have been analyzed in a loop context. Malmborg (1994) has proposed an analytical method for predicting the work in progress storage requirements for a fleet of AGVs serving a loop layout. A pair wise exchange greedy heuristic and a simulated annealing version of it were developed to perform sequential search for the minimization of work in progress storage minimizing line layouts over alternative AGV fleet sizes. Blazewicz et al. (1994) have studied the problem of combining production scheduling with AGV scheduling. Their work, motivated by a real application, examines the case where two AGV loops are interconnected. Hall et al. (2001a) have considered combined job scheduling and material handling in a unidirectional loop: AGVs serve a set of cells each with a combined P/D station located on the loop, and the objective is the minimization of the steady state cycle time required to produce a minimal job set. Three load assignment dispatching rules were proposed. The authors have developed a genetic algorithm and tested it in a layout composed of ten manufacturing cells served by four vehicles. Hall et al. (2001b) have studied the fleet sizing problem. Given the minimum steady state cycle time required to produce a minimal job set, the objective of this model is to minimize the AGV fleet size.

Conclusion

Loop based material flow systems are commonly used in industry and have been proved by several researchers to be highly effective both from a cost and from an operational point of view. Research in this area is rich and has really taken off since the work of Tanchoco and Sinriech in the early 1990s. Because each manufacturing context is in a sense unique and technologies also evolve, we anticipate a continued interest in the study of such problems. This review paper has highlighted some of the main contributions in the field of loop configuration systems. We hope it will inspire researchers and stimulate the study and understanding of new problems.

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