A Material Handling Scheduling System in an Agent Based Environment

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Abstract:
Agent based manufacturing systems are being developed to model and develop control strategies. Material handling systems when modeled as part of agent based system require new strategies for bidding. This paper describes the development of a new scheduling strategy based on priority that can be used for scheduling of material handling systems.

Introduction:

Material handling is the means by which the goal of greater efficiency may be obtained not only in industry but wherever materials must be moved. It offers the greatest opportunity today for the reduction of production costs (Immer, 1953). More importance is given towards material handling system since it is also a key parameter for the performance of an entire manufacturing system. In general, "Material handling means providing the right amount of the right material, in the right condition, at the right place, at the right time, in the right position, in the right sequence, and for the right cost, by using the right method(s)" (Tompkins et al, 1996).

With the advent of agent based systems in manufacturing, there is a need for material handling to be incorporated into the manufacturing system. Most researches that have implemented agent based method for manufacturing have not considered material handling system. Wallace discusses the efficient control of AGVs in complex systems by employing rule based agents such as network agents, loop agents, complex agents, AGV agents and order agents. These agents interact and decide the movement of AGV in the system with the objective of achieving high rate of successful deliveries. (Wallace, A, 2001). Singh and Tiwari employed a multi agent approach in accomplishing the optimal path to be taken by the AGV based on shortest travel time. In determining the optimal path, the intelligent agents consider issues regarding route generation, calculation of time window, finding interruptions and waiting time (Singh and Tiwari, 2002). Heragu et al proposed a hybrid framework to overcome the structural rigidity and lack of flexibility present in the existing hierarchical and heterarchical system. The model consists of three levels, higher level global optimizer agent, middle level guide agent, lower level agents (holons) comprising of part agent, machine agent and material handling device agent. The paper presented a framework to make decisions in both horizontal and vertical directions with different level of agents thus overcoming the structural rigidity and lack of flexibility present in the existing hierarchical and heterarchical system (Heragu,S.S., Graves, R.J., Kim, B. & St, Onge, A., 2002). Agent based method into material handling system and scheduling of machines is done to obtain greater efficiency than the traditional dispatching rules of scheduling material handling vehicles to schedule machines. Yu and Krishnan (2004) developed an agent based model for agile manufacturing. In this model, a scheduling strategy was developed for production control. However this model does not take into consideration the scheduling of the material handling system. This paper describes the development of a priority based rule based on due date, time left to do the job including loaded travel time, job waiting for the system and unloaded travel time, that can be used for the scheduling of material handling systems in an agent based system. The rule has been implemented and tested against traditional rules based systems such as shortest travel time/distance (STT/D) and first come first serve rule (FCFS). STT will cause a big delay or may not even pick up a job which is far away from the machine centre. In the case of FCFS, it will serve jobs coming first into the system but there will be delay because of increased unloaded travel time.

Objective:

To develop a priority based algorithm based on due date, time left to do the job including loaded travel time, job waiting for the system, unloaded travel time with the objective of minimizing the mean tardiness of the jobs in the system and also to minimize the maximum delay.

Multi-Agent Based System

The material handling agent based system is an extension of the multi agent system developed by Yu and Krishnan (2004). The model consists of four multi agents: 1) cooperation agent, 2) job management agent, 3) resource broker agent, and 4) resource control agent. The material handling resource control agent is added at the same hierarchy level as the job management agent and material handling vehicle agent in the lowest level along with the resource control agent. The cooperation agent has the list of existing orders that needs to be performed by the job management agents in the next lower level. The material handling control agent determines the number of vehicles required to perform the task. The material handling resource control agent bids through the resource broker agent for each operation to the job management agents higher in the level. Based on the analysis of the bids, the job management agent identifies the material handling agent that will perform the task. The material handling vehicle agent bids for each of operation based on due date priority, time needed to complete the job. The best bid is then used to assign tasks to vehicles. When there are more jobs to be moved than available vehicles, then the algorithm calculates the priority for each job. Since the focus of this paper is to develop the scheduling strategy for material handling systems, the details of the agent based system will be elaborated in a different paper.

Definition of Symbols

m – total number of operations for a job
t_c – current time, min;
t_a – average processing time, which includes loaded travel time, loading and unloading time and the operation times, for all waiting jobs, min;
t_{ris} –time at which the vehicle is required to pick up job i at stage s, min;
t_{uis} – unloaded travel time to pick up job i at stage s, min;
d_i – due date of job *i*, min;
d_f– due date multiplication factor;
t_{ci}– completion time of job *i*, min;
t_l – loading time assumed to be uniform, min;
t_u – unloading time assumed to be uniform, min
t_{pis} – time required for processing of job i at stage s, min
t_{lis} - loaded travel time from stage s to stage s+1
k =3, look ahead parameter for dynamic material handling scheduling. (based on the predicted number of competing jobs, the k value scales the slack). The value of k was determined after conducting numerous trials for different integer values. As the value of k increased or decreased, maximum delay and mean tardiness of jobs also increased.

Scheduling Strategy for Material Handling Systems

Vepsalainen and Morton (1987) developed a priority based strategy for scheduling of jobs within a job shop system. The system utilized the available slack time to determine the priority of the jobs. The concept of slack time to calculate the priority has been utilized to develop a priority based rule for the scheduling of material handling systems. The priority rule for material handling is given in equation 1.

$$MHR(i,s)= [\exp(-(d_i - \sum_s^m t_{tli} - t_c))/(k^* t_a)]^*\exp[t_c/t_{ris}]^*(1/t_{uis}) \quad (1)$$

$$\sum_s^m t_{tli} = \sum_s^m t_{pis} + \sum_s^m t_{lis} + (t_l+t_u)\sum_s^m s \quad (2)$$

In this expression, the total loaded travel time, loading time and unloading time is added to the processing time of the job (equation 2). Distance between work centers and hence the travel time is an important factor to be considered in job shop scheduling. It is important that loaded travel time be considered in the expression as it will increase the priority of the job more by reducing the slack, thus picking up earlier and hence minimizing tardiness. $1/t_{uis}$ in equation 1 will increase the bid value for the vehicle closer to the job and hence minimizing the unwanted unloaded travel time of the vehicle and also reduces the tardiness of the job. The term $\exp[t_c/t_{ris}]$ is considered so that the jobs that come earlier gets a greater priority than the later jobs. As the current time keeps increasing the term (t_c/t_{ris}) increases exponentially to a high value and thereby increasing the priority of jobs that come earlier into the system. So if there are two jobs with identical slack times the job that came into the system earlier will be given higher priority.

Implementation of Scheduling

To study the effectiveness of the priority based material handling strategy, sample experimental case studies were developed. The implementation of the proposed material handling rule is done in a FMS environment with unequal floor spacing for machines. In this case study, AGV material handling system is considered for the movement of parts between machine centers. The layout consists of three machines M1, M2, M3. The machines are linked to each other by an AGV track as shown in the Figure 1. The machine centers are assigned a delivery point and a pick up point. For machine center M1, "2" is the delivery point and "3' is the pick up point. Similarly, "4" and "6" are the delivery points and "5" and "7" are the pick up points for work centers M2 and M3 respectively. New jobs are picked up from point "1" and completed jobs are delivered to point "8". In this layout, there are 12 unidirectional path segments. The positioning of delivery and pickup station for each work centre is not necessarily at the centre of a track segment. Traffic blocking or segment blocking is not considered in this layout.

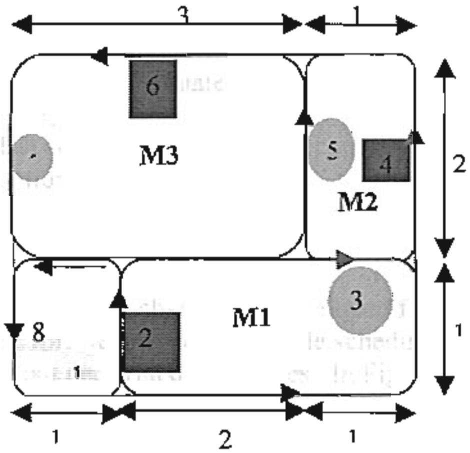

Figure 1. Machine Centre layout with AGV routings.

Job	Machine sequence	Processing times in minutes
J1	M1, M3	(4-6), (6-8)
J2	M1, M2	(2-4),(2-4)
J3	M3	(7-9)
J4	M1, M3	(5-7),(5-7)

Table 1. Jobs and Process Sequence

Table 1 shows the job sequence and processing time for the 4 jobs considered in this case study. A fixed inter-arrival time and a rectangular distribution are used for the jobs. The machine capacity at the work centre considered is infinite. There are no regulations on the input or output queue size. As vehicle collision or path blocking is not considered there can be more than one vehicle using the same route at a given time. Variable processing time is assigned to the each processing stage of the job.

Simulation

The case study is experimented for three different inter arrival times (5, 7 and 10 minutes). The due dates assigned = $t_c + (d_f * \text{total processing time})$. The warm up period for the simulation is 2000 minutes. The simulation is executed for all jobs that enter the system for a period of 10 days. The simulation is run until all jobs that have come during this period are completed. Prior to the implementation of the scheduling system, the number of vehicles needed was determined using the algorithm developed by Egbelu (1987). In this algorithm the loaded travel time is considered as equal to the unloaded travel time. New jobs come into the system at a given interval time. The number of vehicles for inter arrival time of 5, 7, 10 are 4, 3, and 2 respectively. The dispatching rules that were used for the simulation are Shortest Path Taken (SPT), First Come First Serve (FCFS) and Earliest Due Date (EDD) and the new priority rule.

During the simulation, when a vehicle is free, it asks the material handling resource control agent to broadcast the jobs that needs to be picked up and delivered to the respective stations. The vehicle agent calculates bidding value for each of the jobs waiting for material handling vehicle using the dispatching rule and sends the information to the material handling resource control agent. The material handling resource control agent selects the job with the maximum bid, which minimizes the maximum delay and the mean tardiness. The vehicle agent is assigned the appropriate job for pickup and delivery.

If multiple vehicles are free, then these vehicle agents will request the material handling resource control agent to broadcast the jobs that needs to be picked up. Then each vehicle agent will submit their bids to the material handling resource control agent for the jobs in the waiting queue. The material handling resource control agent assigns the vehicle that submitted the maximum bid for the job to pick up. Similarly, other free vehicles are assigned to jobs.

The next required time or pick up time is then calculated for the job using the below equation.

$$t_{ris} = t_c + t_{uis} + t_l + t_{lis} + t_u \quad (3)$$

If the job that is picked up is in the last stage then calculate the completion time of the job using the same above right hand side part of the equation.

$$t_{ci} = t_c + t_{uis} + t_l + t_{lis} + t_u \quad (4).$$

Results

Based on the simulation results several charts were developed for analysis. Based on analysis of the plots, it can be seen that the MHR rule developed for vehicle scheduling to minimize mean tardiness and maximum delay has consistently out performed other rules. In Figure 2, the maximum delay has been plotted against the due date factor. For all due date factors, the maximum delay of MHR rule is considerably lower than other dispatching rules. EDD has performed better than FCFS in most cases as it depends on the earliest due date of completion and FCFS depend on the first job waiting in any queue that requests for the vehicle. In the case of SPT, the maximum delay is high because it has failed to take jobs from stations that are farther away, hence increasing the delay.

The mean tardiness using the MHR is considerably low compared to the other dispatching rules. Figure 3 shows a plot of mean tardiness vs. due date factor. The mean tardiness using the SPT rule is high since it is unable to pick up the jobs that are further away. As a result of this some jobs gets delayed more and hence the mean tardiness of the job increases. EDD has performed better than FCFS and SPT in this case as it depends on the earliest due date of completion.

In Figure 4, the maximum delay has been plotted against the number of vehicles for an inter arrival time of 5. As per Egbelu's (1987) analytical approach, the minimum calculated number of vehicles required is 4 for inter arrival time of 5. When the number of vehicles is reduced below the minimum vehicle requirement, the maximum delay increased steeply for all rules. It can be seen from Figure 4 that MHR has outperformed all other rules consistently. EDD has performed better than FCFS and SPT since the EDD rule depends on the earliest due date of completion. In the case of SPT, the maximum delay is high because it has failed to take jobs from stations that are farther away, hence increasing the delay.

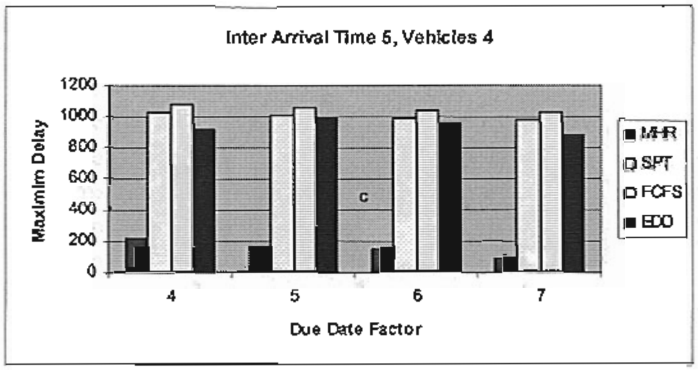

Figure 2. Maximum Delay vs. Due Date Factor

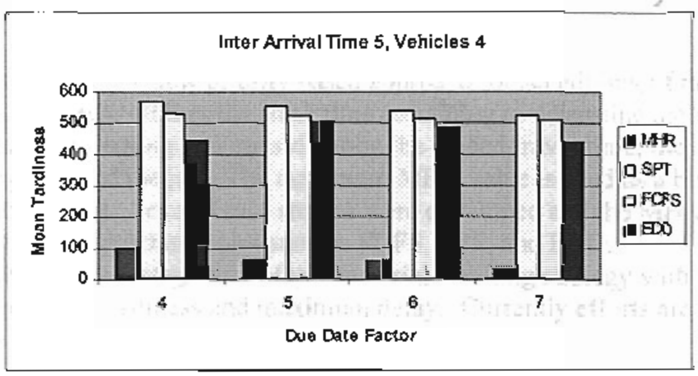

Figure 3. Mean Tardiness vs. Due Date Factor

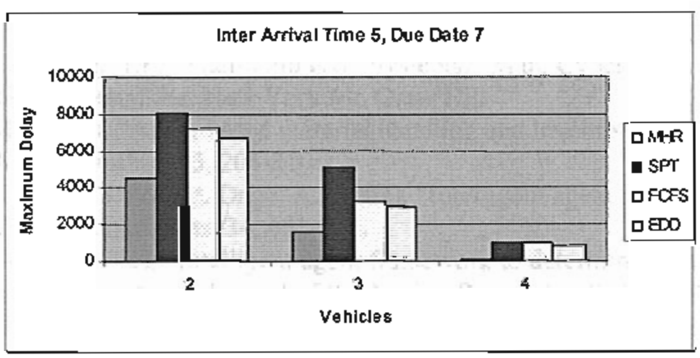

Figure 4. Maximum Delay vs. # of Vehicles

In Figure 5, the mean tardiness has been plotted against the number of vehicles for an inter arrival time of 5. The mean tardiness using the MHR is considerably low compared to the other dispatching rules. EDD has performed better than FCFS and SPT since the EDD rule depends on the earliest due date of completion. When fewer number of vehicles is used the mean tardiness of FCFS and EDD is high because of increase in unloaded travel time by the vehicles to pick up the jobs. The mean tardiness for SPT rule is high since it is unable to pick up the jobs that are further away. As a result of this some jobs gets delayed more and hence the mean tardiness of the job increases.

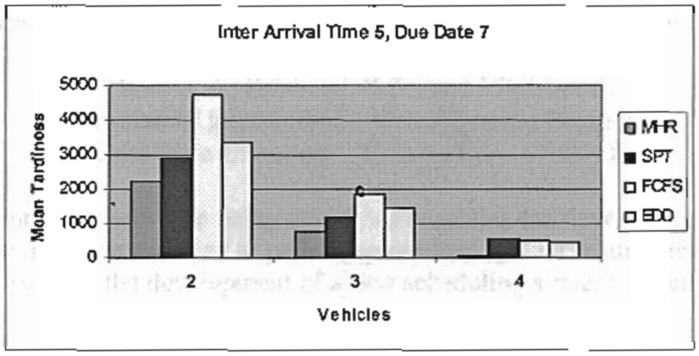

Figure 5. Mean Tardiness vs. # of Vehicles

Conclusion:

This paper has presented a new priority based approach for scheduling of material handling systems. The priority based rule utilizes the slack time remaining to determine the priority of the jobs. The slack time is estimated by taking into consideration the loaded travel time, the loading and unloading time and the processing times of the job. The maximum MHR value is used as a bid to the material handling resource control agent. Several case studies were developed and the MHR rule consistently performed better than other dispatching rules such as FCFS, SPT, and EDD.

Future research involves integration of this material handling strategy with the job scheduling strategy to minimize the mean tardiness and maximum delay. Currently efforts are on-going to further validate the rules developed using larger number of case studies.

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