Available online at www.sciencedirect.com
ScienceDirect
Computers & Operations Research 34 (2007) 1688–1707
computers & operations research
www.elsevier.com/locate/cor

Scheduling and routing of automated guided vehicles: A hybrid approach

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Available online 3 October 2005

Abstract

We propose a hybrid method designed to solve a problem of dispatching and conflict free routing of automated guided vehicles (AGVs) in a flexible manufacturing system (FMS). This problem consists in the simultaneous assignment, scheduling and conflict free routing of the vehicles. Our approach consists in a decomposition method where the master problem (scheduling) is modelled with constraint programming and the subproblem (conflict free routing) with mixed integer programming. Logic cuts are generated by the sub problems and used in the master problem to prune optimal scheduling solutions whose routing plan exhibits conflicts. The hybrid method presented herein allowed to solve instances with up to six AGVs.

Keywords: Constraint programming; Mathematical programming; Hybrid model; Logical Benders decomposition; Material handling system; Automated guided vehicles; Vehicle routing and scheduling

1. Introduction

This study focuses on the simultaneous scheduling and routing of automated guided vehicles (AGVs) in a flexible manufacturing system (FMS). An AGV is a material handling equipment that travels on a network of guide paths. The FMS is composed of various cells, also called working stations, each with a specific function such as milling, washing, or assembly. Each cell is connected to the guide path network by a pick-up/delivery (P/D) station where pallets are transferred from/to the AGVs. Pallets of products are moved between the cells by the AGVs. The guide path is composed of aisle segments on which the vehicles are assumed to travel at a constant speed. The vehicles can travel forward or backward. As many vehicles travel on the guide path simultaneously, collisions must be avoided. AGV systems are

0305-0548/$ - see front matter © 2005 Published by Elsevier Ltd.
doi:10.1016/j.cor.2005.07.004

implemented in various industrial contexts: container terminals, part transportation in heavy industry, flexible manufacturing systems. For a general review on AGV problems, the reader is referred to [1–3]. For a recent review on AGVs scheduling and routing problems and issues, the reader is referred to the survey of Qiu et al. [4]. These authors identified three types of algorithms for AGVs problems: (1) for general path topology, (2) for path optimization and (3) for specific path topologies. Methods of the first type can be divided in three categories: (1a) static methods, where an entire path remains occupied until a vehicle completes its route; (1b) time-window based methods, where a path segment may be used by different vehicles during different time-windows; and (1c) dynamic methods, where the utilization of any segment of path is dynamically determined during routing rather than before as with categories (1a) and (1b). The method presented in this article belongs to the third category (1c) and addresses the conflict free routing problem with an optimization approach. The plan of the article is as follows. Section 2 presents a description of the problem. Section 3 reviews the relevant works. Section 4 presents the hybrid constraint programming (CP)/mixed integer programming (MIP) approach. Section 5 describes in detail the experimentation. The conclusion follows.

2. Problem description

Every day, a list of orders is given, each order corresponding to a specific product to manufacture (here, product means one or many units of the same product). The product units are carried on pallets by the AGVs and the unit load is one pallet. Each order determines a sequence of operations on the various cells (machines) of the FMS. Fig. 1 presents the FMS with the AGV guide path used in the experimentation. The production scheduling, i.e., setting the earliest starting time of each machine operation for each pallet of each order, is done a priori using the P.E.R.T. method. Hence, each material handling request is composed of the pick-up and the delivery of a specific pallet with the corresponding earliest times. The guide path network is bi-directional. The vehicles can stop only at the ends (intersection nodes) of the guide path segments. There are two types of possible collisions: the first type may appear when two vehicles are moving toward the same node. The second type of collision occurs when two vehicles are traveling head-to-head on a segment. A production delay is incurred when a load is delivered after its planned earliest time. The problem is thus defined as follows:

Given a number of AGVs (and their starting positions) and a set of transportation requests, find the assignment of the requests to the vehicles and conflict free routes for the vehicles in order to minimize the sum of the production delays.

A solution of the problem determines:

- The number of AGVs required to perform the set of tasks.
- The assignment of requests to the AGVs.
- The position of each AGV at each period in the FMS.
- The schedule of each pick-up or delivery task.
- The revised schedule for each machine given the transportation schedule.

Our problem may be seen as a vehicle routing problem with time windows (VRPTW) in which the objective is to minimize the sum of deviations from the lower bound value of the time windows of the