Conflict-free Real-time AGV Routing

Rolf H. Möhring, Ekkehard Köhler, Ewgenij Gawrilow, and
Björn Stenzel

Technische Universität Berlin, Institut für Mathematik, MA 6-1,
Straße des 17. Juni 136, 10623 Berlin, Germany
{moehring,ekoehler,gawrilow,stenzel}@math.tu-berlin.de

Abstract. We present an algorithm for the problem of routing Automated Guided Vehicles (AGVs) in an automated logistic system. The algorithm avoids collisions, deadlocks and livelocks already at the time of route computation (conflict-free routing). After a preprocessing step the real-time computation for each request consists of the determination of a shortest path with time-windows and a following readjustment of these time-windows. Both is done in polynomial-time. Using goal-oriented search we get computation times which are appropriate for real-time routing. Additionally, in comparison to a static routing approach, used in Container Terminal Altenwerder (CTA) at Hamburg Harbour, our algorithm had an explicit advantage.

1 Introduction

Nowadays automation in logistic systems is very popular. In such an automated logistic system Automated Guided Vehicles (AGVs) are used for transportation tasks and the control of these AGVs is the key to an efficient transportation system. Usually, the aim is to maximize the throughput.

Here, control means computation of routes (routing) on the one hand and collision avoidance on the other hand. The assignment of transportation tasks to AGVs is not part of this work.

Various aspects of the considered problem are of importance. The routes must be computed in appropriate time (for a real-time computation) with respect to the physical properties of the AGVs. The collision avoidance particularly has to deal with the dimensions of the AGVs. In our approach collisions are avoided already at the time of route computaion. This is called conflict-free routing.

One of the first paper on routing (free-ranging) AGVs without causing collisions was done by Broadbent et al. [3] in 1987. Krishnamatury, Batta and Karwan [9] discussed the problem for the special case when all requests are known right from the beginning.

We consider the online problem where requests appear sequentially and one must answer each request without having any information about later arriving requests. We extend the approaches of Huang, Palekar and Kapoor [7] and Kim and Tanchoco [8], respectively. In particular, we take physical properties of the AGVs into consideration in a more exact and flexible way and present an efficient algorithm for the problem.

2 The Model

Let $G = (V, A)$ be a directed graph which represents the lanes of the automated transportation system and let $\tau(a)$ be the transit time on arc a. Then an online routing algorithm has to deal with a sequence $\sigma = r_1, \dots, r_n$ of requests. Each request $r_j = (s_j, t_j, \theta_j)$ represents a task with start node s_j and end node t_j while θ_j denotes the desired starting time.

2.1 Problems with static routing approaches

In static approaches for this problem one computes a route without taking time dependencies into consideration. This can be done by standard shortest path algorithms, i.e., the Dijkstra algorithm (see [4]). In such an approach congestion can be considered by additionally using load dependent arc costs (see [1]). The arising routes are not conflict-free and therefore one needs an additional conflict management at real-time. To guarantee that there are no collisions the moving AGVs must allocate the area they want to use next.

The advantage of this approach is clear: it is easy to implement a fast routing algorithm. But the disadvantages of the described collision avoidance, namely the appearance of deadlocks and livelocks (see Fig. 1), have an enormous effect on the performance of the system.

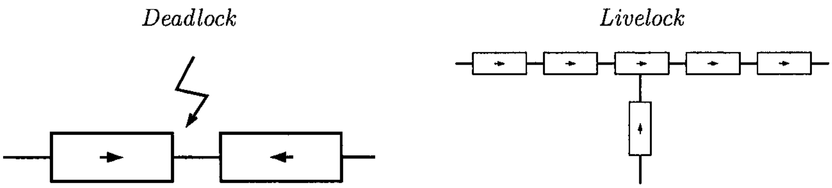

Fig. 1. Deadlocks and Livelocks

Deadlocks appear if two or more AGVs wish to allocate the same area. None is able to continue its route and the system is blocked. Livelock is the generic term for situations where an AGV is blocked repeatedly by other AGVs without having the possibility of allocating the area which is next on its route.

2.2 Conflict-free routing

In order to avoid the problems of the simple model given in Section 2.1, we compute conflict-free routes because in a conflict-free approach there is no need for an additional collision avoidance.

There are two key ingredients which must be considered in that approach. On the one hand, one has to deal with the physical dimensions of the AGVs