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Motion Planning Problem of Automated Guided Vehicles

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To increase the efficiency and to reduce distribution cost are important objectives in the field of logistics and distribution systems. Recently, factory automation (FA) and flexible manufacturing systems (FMS) are widely introduced in many companies for the purpose of producing small amount of various kinds of products. The typical technologies of FA are automatic warehouse system, product design, and manufacturing plant automation by using machine tools.

Moreover, production lines are integrated through automating the whole production process in the factory. As a result, efficiency and preciseness of the work are improved, and working cost and personnel expenses are reduced.

The automatic carriage system using automated guided vehicles (AGVs) is one of important technologies of FA and FMS. Each AGV runs automatically along tracks built in the factory, and carries parts or goods to be delivered. The automatic carriage system using AGV (AGV system) has flexibility in variations of circumstances. For example, cooperative carriage can be realized by allowing communication between AGVs, and autonomous control of AGVs is also possible. To realize such intelligent control, we need control software that supervises all AGVs so that they run without collision and also satisfy given requirements.

There are many problems for controlling the AGV system. For example, assigning carriage requests to available AGVs, finding optimum routes, and motion planning of AGVs. These problems have been studied as the routing problem and the scheduling problem.

When there exists more than one AGV in the same carriage system, avoiding collision between AGVs is one of the fundamental problems to be considered. Several approaches have been proposed to avoid the collision, such as methods using heuristics, graph theoretical approach, and introducing appropriate sidetracks.

In this paper, the following situation is considered for an automatic carriage system using AGVs. The considering carriage system is a system in which each AGV carries some goods received from a specified plant, and delivers it to a specified plant. Each AGV runs on tracks laid in advance. When AGV runs toward one direction and another AGV runs in the opposite direction, they cannot pass through each other without collision. Moreover, while each AGV are running from the starting position to the finishing position, it cannot add or remove any carrying goods. Regardless of the amount of carrying goods, the ability of transportation of each AGV, such as the running spped, is assumed to be constant. In addition, we assume that every AGV has the same ability of transportation and carrying capacity. Each AGV has to receive some goods from a plant (starting position) at the specified time (starting time), and to deliver it to a plant (finishing position) at the specified time (finishing time). The Carriage requests are a set of pairs $\{(starting\ time, starting\ place), (finishing\ time, finishing\ place)\}$ on the condition that they does not change before the plans of all AGVs are completed, i.e., the requests are static. The purpose of this research is to decide positions of each AGV at each discrete time so that they satisfy the given carriage requests.

In this thesis, we have proposed an algorithm that computes a motion plan without collision between AGVs. It is guaranteed that the proposed algorithm always obtains a motion plan without collision between AGVs if such it exists. The inputs of the proposed algorithm are the network describing tracks, the number of AGVs, the initial position of each AGV, and carriage requests. The corresponding outputs are the position of each AGV at every discrete time. Suppose that there are k AGVs in the carriage system. Then, the motion plan is obtained by finding k disjoint paths in the graph such that each nodes represents a position at some discrete time and each arc represents a possible movement between two positions. Here, we put the following assumptions:

1. the number of carriage request is equal to the number of AGVs, and

2. each AGV satisfies exactly one carriage request.

The motion plan consists of three stages. The first stage decides the movement of each AGV from its initial position to the starting position of the carriage request assigned to it. The second stage decides the movement of each AGV from the corresponding starting position to the corresponding finishing position. The third stage decides the movement of each AGV from the corresponding finishing position to a position at the time when the plans of all AGVs are completed. The running time of this algorithm is bounded by an exponential function of k, the number of AGVs(the number of carriage).

In the future, we will consider conditions on which the problem is solvable in polynomial time, and the case that the number of carriage request is not equal to the number of AGVs. We will also study the problem in which the carriage requests are given dynamically.