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Centralized fleet management system for cybernetic transportation

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ABSTRACT

In this article, we present a centralized fleet management system (CFMS) for cybernetic vehicles called cybercars. Cybercars are automatically guided vehicles for passenger transport on dedicated networks like amusement parks, shopping centres etc. The users make reservations for the vehicles through phone, internet, kiosk etc and the CFMS schedules the cybercars to pick the users at their respective stations at desired time intervals. The CFMS has centralized control of the routing network and performs pooling of customer requests, scheduling and routing of cybercars to customers, empty cybercars to new services or parking stations and those running below their threshold battery levels to recharging stations. The challenges before CFMS are to assure conflict-free routing, accommodate immediate requests from customers, dynamic updation of vehicle paths and minimize congestion on the whole network. We present the approaches used by CFMS to ensure these functionalities and demonstrate a numerical illustration on a test network.

1. Introduction

In many urban environments, private automobile use has led to severe problems with respect to congestion, energy (our dependency on oil resources), pollution, noise, safety and general degradation of the quality of life. Therefore, historical cities centers are facing severe problems, traditional commerce in them declines, moving to the periphery, and they become less attractive to tourists. Although public transport systems have seen many recent improvements (mostly due to information technologies), in many cases the car still offers a much better service at the individual level. A new approach for mobility, emerging now as an alternative solution to the private passenger car, offers the same flexibility and much less nuisances are small automated vehicles that form part of the public transportation system and complement mass transit and non-motorised transport, providing passenger service for any location at any time. Such systems can also evolve to provide door-to-door freight delivery or garbage collection. Experiments are under way in several places in Europe and in Japan and the first operational system (the ParkShuttles) have been in use in the Netherlands since the end of 1997 and is now being expanded.

This concept started with car-sharing: a fleet of individual vehicles shared among a relatively large number of users, offers the possibility of using a car for some time or having a car available at both ends of a train trip. These systems are increasingly popular in Switzerland and Germany. Specific vehicles, well-adapted to city driving, have generally been used for these systems: small size, convenient, energy efficient, quiet, often based on electric power. They even compete with public transportation in terms of energy consumption on per passenger-km basis. To date, these systems have not generally proven that they can compete economically, one reason being limited vehicles availability in too few locations, thus limiting the number of potential customers (European Project Utopia, 2002–2004).

A novel form of vehicle-sharing is now appearing, mostly in Europe, based on automated vehicles, avoids this problem of availability (anywhere and anytime). The car has automated driving capabilities on an existing road infrastructure, with a right of way similar to dedicated bus-lanes. Some vehicles also allow traditional manual driving for running in normal traffic. In such cases, they are called dual-mode and their automated capabilities allow them to be collected and distributed by platooning or remote control. The CyberCars Project (Parent & Gallais, 2003) was dedicated to the development and dissemination of a new form of urban transport based on cybercars, which are road vehicles with fully automated driving capabilities. Such innovative transport system

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Fig. 1. Yamaha AGV at floriades.

can provide on demand and door-to-door capabilities for passengers or goods. Fig. 1 shows a cybercar in action at Floriades.

Cybercars by definition are under control of a management system in order to adapt the resources to the demand. Since it is expected that a large number of users will have access to a large number of vehicles, it was necessary to develop sophisticated management tools in order to optimize the use of the mobile resources which are not only the vehicles but also the human resources for running smoothly the system (for maintenance, assistance, cleaning, etc.) and the physical resources such as parking places, recharging stations, etc. Such systems had already been developed for car-sharing systems and for industrial AGVs (Parent, Benejam-Fraqois, & Hafez, 1996). However, such systems had to be adapted to the particular problems of public transportation with automated vehicles. For example, the redistribution problem of empty vehicles among the different parking lots with car-sharing systems, human transport problem for industrial AGVs, whose infrastructures and technologies in the previous years were mainly focused on material handling systems (MHS) rather than human transport. Furthermore, the fact that the vehicles could be moved autonomously changed the problem by allowing many more "stations" for pick-up or destinations.

The fleet management problems for vehicles have been widely reported in literature. Cheung, Choy, Li, Shi, and Tang (2008) present a mathematical model for dynamic fleet management that captures the characteristics of modern vehicle operations. Belmonte, Pérez-de-la-Cruz, and Triguero (2008) present the design and implementation of a multi-agent decision support system for the bus fleet management domain. Beaulieu and Gamache (2006) present an enumeration algorithm based on dynamic programming for optimally solving the fleet management problem in underground mines. Horn (2002) describes a software system designed to manage the deployment of a fleet of demand-responsive passenger vehicles such as taxis or variably routed buses. Adler and Bule (2002) present a cooperative multi-agent transportation management and route guidance system. Andersen, Crainic, and Christiansen (2009) present an optimization model for the tactical design of scheduled service networks for transportation systems. Renaud and Boctor (2002) present a sweep-based heuristic for the fleet size and mix vehicle routing problem. Kochel et al. (2003) develop a modeling approach integrating queuing theory, simulation and genetic algorithms for optimal control of a distributed service system with moving resources and demonstrate its application to the fleet sizing and allocation problem. Li and Tao (2010) develop a develop a two stage dynamic programming model on determining optimal fleet size and vehicle transfer policy for a car rental company. Pasquier, Quek, Tan, and Chee (2001) propose a heuristic solution to the Dynamic Transportation - Planning Problem using a Blackboard-based approach. Wang, Yang, and Yang (2006),Wang, Yang, and Yang (2008) present agent based models for cybernetic transportation. Dror (1998) and Hafez, Parent, and Proth (2001) present a model for distribution of self-service electric cars. Laporte and Smet (1999) and Gillett and Miller (1974) present heuristics for vehicle routing problems. Among these research works, the problems solved in Pasquier et al. (2001), Dror et al. (1998), Hafez et al. (2001) and Wang et al. (2006),Wang et al. (2008) fall close to the context of our problem.

2. Problem description

The remote control of cybercars from the central management system was found necessary not only for the monitoring of the state of the vehicles (location, mode of usage, energy, etc.), but also for the possibility to remotely drive the vehicles (Awasthi, Benabid, Talamona, & Parent, 2003). This was considered as an important back-up function for the automatic driving when a vehicle is stopped for an unknown reason: emergency switch activated by someone, obstacle, hardware or software malfunction, etc. In these cases, it would be convenient for the operator in the control room to take control of the vehicle and see if he/she can eventually operate it. If the remote driving is possible, then the conflict could potentially be resolved and the vehicle returned to its automatic mode or removed from the operation. Remote driving of road vehicles had already been demonstrated several times, for example for army vehicles and for maintenance vehicles because of the potentially dangerous situations. In a city environment, the difficulty lied with the environment, which might be unpredictable (moving vehicles and/or pedestrians).