ABSTRACT

Fully autonomous vehicles promise enormous gains in safety, efficiency, and economy for transportation. In previous work, the authors of this chapter have introduced a system for managing autonomous vehicles at intersections that is capable of handling more vehicles and causing fewer delays than modern-day mechanisms such as traffic lights and stop signs [Dresner & Stone 2005]. This system makes two assumptions about the problem domain: that special infrastructure is present at each intersection, and that vehicles do not experience catastrophic physical malfunctions. In this chapter, they explore two separate extensions to their original work, each of which relaxes one of these assumptions. They demonstrate that for certain types of intersections—namely those with moderate to low amounts of traffic—a completely decentralized, peer-to-peer intersection management system can reap many of the benefits of a centralized system without the need for special infrastructure at the intersection. In the second half of the chapter, they show that their previously proposed intersection control mechanism can dramatically mitigate the effects of catastrophic physical malfunctions in vehicles such that in addition to being more efficient, autonomous intersections will be far safer than traditional intersections are today.
INTRODUCTION

Recent advances in technology have made it possible to construct a fully autonomous, computer-controlled vehicle capable of navigating a closed obstacle course. The DARPA Urban Challenge [DARPA 2007], at the forefront of this research, aims to create a full-sized driverless car capable of navigating alongside human drivers in heavy urban traffic. It is feasible that, in the near future, many vehicles will be controlled without direct human involvement. Our current traffic control mechanisms, designed for human drivers, will be upgraded to more efficient mechanisms, taking advantage of cutting-edge research in the field of Multiagent Systems (MAS).

Intersections are one aspect of traffic control that are particularly compelling multiagent systems. Often a source of great frustration for drivers, intersections represent both a sensitive point of failure as well as a major bottleneck in automobile travel. While fully autonomous open-road driving was demonstrated over ten years ago, events such as the DARPA Urban Challenge prove that city driving, including intersections, still pose substantial difficulty to AI and intelligent transportation systems (ITS) researchers.

Managed Intersection Control

Previously, we proposed an intersection control mechanism to direct autonomous agents safely through an intersection [Dresner & Stone 2005]. This system is based on the interaction of two classes of agents: intersection managers and driver agents. Driver agents “call ahead” to an intersection manager at the intersection, reserving the time and space needed to cross. Specifically, when approaching an intersection, a driver agent sends a request message containing a predicted arrival time and velocity, along with basic information about the vehicle it is controlling. The intersection manager responds with either a confirmation message containing details of the approved reservation, or a denial message, signaling that the parameters sent by the driver agent are unacceptable. In the case of confirmation, the driver agent will attempt to meet the parameters of the reservation, and will cancel the reservation if it cannot. In the case of denial, the driver agent must try to make a different reservation.

Intersection managers base their decisions on the supplied parameters and an intersection control policy. The most efficient policies, including FCFS or “first come, first served”, simulate the trajectory of the vehicle through the intersection. At each stage in the simulation, the intersection manager checks whether the vehicle is within a certain buffer distance of any other vehicle in the intersection. If the requesting vehicle can cross the intersection without entering any space-time reserved by another vehicle, the policy creates the reservation, and the intersection manager approves the request. Otherwise, the policy does not create a reservation, and the intersection manager denies the request. By integrating these policies with traditional traffic light systems, we have also demonstrated that the system can accommodate human traffic [Dresner & Stone 2007]. This multiagent approach offers substantial efficiency benefits as compared to existing mechanisms, such as traffic lights and stop signs. Vehicles pass through the intersection faster, and congestion at intersections is significantly reduced.

Although at the city level this system is mostly decentralized, at each individual intersection, traffic is coordinated by a single arbiter agent, the intersection manager. We therefore designate this system a managed intersection control mechanism. An intersection controlled by a traffic light is also a managed intersection—the traffic light being the arbiter agent. Conversely, we designate intersection control