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Autonomous vehicle control systems for safe crossroads

Javier Alonso *, Vicente Milanés, Joshué Pérez, Enrique Onieva, Carlos González, Teresa de Pedro

Centro de Automática y Robótica (CAR), UPM-CSIC, Carretera de Campo Real, km. 0.200, 28500 La Poveda, Arganda del Rey, Madrid, Spain

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ABSTRACT

This article presents a cooperative manoeuvre among three dual mode cars – vehicles equipped with sensors and actuators, and that can be driven either manually or autonomously. One vehicle is driven autonomously and the other two are driven manually. The main objective is to test two decision algorithms for priority conflict resolution at intersections so that a vehicle autonomously driven can take their own decision about crossing an intersection mingling with manually driven cars without the need for infrastructure modifications. To do this, the system needs the position, speeds, and turning intentions of the rest of the cars involved in the manoeuvre. This information is acquired via communications, but other methods are also viable, such as artificial vision. The idea of the experiments was to adjust the speed of the manually driven vehicles to force a situation where all three vehicles arrive at an intersection at the same time.

1. Introduction

This work was done as part of the AUTOPIA project. The Robotics and Automation Centre (CAR), a joint research centre of Spain's Superior Scientific Research Council (CSIC) and the Polytechnic University of Madrid started the AUTOPIA project in 1996. The research group has been working towards the full automation of autonomous vehicles in urban areas, and is now focusing on cooperative manoeuvres among cars.

The research centre has developed three dual mode cars, and has an experimental track that is designed to resemble an urban area (see Section 4). These cars are fully automated, but can also be operated manually. The accelerator, the brake, and the steering wheel of the vehicles have been automated and are controlled by a computer. The vehicles are also equipped with differential GPS, inertial measurement units (IMU), magnetic compass, and wheel encoders to provide precise positioning (Milanés et al., 2008). The car position is compared with the map of the desired route, and a fuzzy controller sends the needed orders to the accelerator, the brake, and the steering wheel to keep the car on its route (Onieva et al., 2009).

From 2005 to 2008, the AUTOPIA group lead the Control Algorithms package of the European project "EU STREP FP6-028062 CyberCars2: Close Communications for Cooperation between CyberCars" (CC2). A common architecture and a communications standard were developed to allow cooperation between the consortium partners: TNO (Holland), INRIA (France), CRF (Italy), and AUTOPIA (Spain) (Naranjo et al., 2009). But to perform cooperative manoeuvres among several autonomous vehicles, a new algorithm to resolve priority conflicts at intersections was also needed (Alonso, 2009).

The present communication presents two methods of establishing road junction priorities. The first proposed solution uses priority tables, and was the result of an exhaustive study of the different scenarios that may occur at an intersection. The second is a simplification of the first, taking advantage of the knowledge gained in the initial study of the manoeuvre to provide a solution based on priority levels.

* Corresponding author.
E-mail addresses: javier.alonso@car.upm-csic.es (J. Alonso), vicente.milanes@car.upm-csic.es (V. Milanés), joshue.perez@car.upm-csic.es (J. Pérez), enrique.onieva@car.upm-csic.es (E. Onieva), carlos.gonzalez@car.upm-csic.es (C. González), teresa.depedro@car.upm-csic.es (T. de Pedro).

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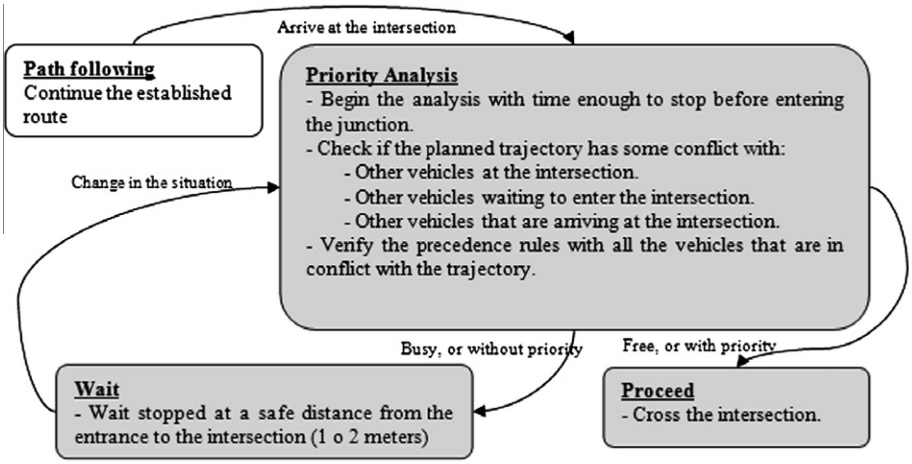

Fig. 1. General scheme of the intersection manoeuvre.

Each of the autonomous vehicles acts independently. In other words, the control and the decision making system of each vehicle is individual, and depends on the vehicle's current status and the information the system has about the environment. The state at a junction or intersection is described from the viewpoint of one of the vehicles which will be termed the reference vehicle, although each vehicle at the intersection will have to take its own decisions, and all should be consistent. The movement of the cars will be studied from the standpoint of the reference vehicle, and other cars will be referred to according to the direction in which they are approaching the intersection.

The goal of the present work was to permit the vehicles to undertake the mission of coordination so that no central coordinating organ is necessary, i.e., there is no need for infrastructure modifications. The improvement in the management of the flow of vehicles at intersections is expected to reduce traffic congestion problems, since the capacity of intersections is 50% less than the capacity of the route (Board, 2000). We define an intersection as a crossing of two-way roads without any traffic lights managing it. The general outline of the procedure governing the manoeuvre through an intersection for a vehicle is shown in Fig. 1.

2. Autonomous vehicles

This section presents the autonomous vehicles used in the experiments (Fig. 2). AUTOPIA's new intersection decision system was implemented on a Citroen C3 Pluriel which is capable of performing autonomous driving. The vehicle is equipped with a double-frequency GPS receiver running in RTK carrier phase differential mode that supplies 2 cm resolution positioning at a refresh rate of 5 Hz. To avoid degradation of the positioning when the correction signal is lost, the vehicle uses its own odometry supplied by a set of built-in sensors in the wheels whose measurements can be read by accessing the Controller Area Network (CAN) bus of the vehicle, and a Crossbow IMU300CC inertial measurement unit (IMU) placed close to the centre of the vehicle. This system allows automated vehicle guidance in urban areas. We have tested this autonomous guidance system for up to 5 min before the drift becomes too large (Milanés et al., 2008).

Fig. 2. The CAR's autonomous vehicles.