Traffic Light Intelligent Regulation Using Infrastructure Located Sensors

Javier Alonso, Jorge Godoy, Roberto Sanz, Enrique Onieva, Vicente Milanés, Jorge Villagrá, Carlos González, Teresa de Pedro, and Ricardo García

Centro de Automática y Robótica, UPM-CSIC. Arganda del Rey, 28500 Madrid, Spain
{javier.alonso,jorge.godoy,roberto.sanz,enrique.onieva, vicente.milanes,jorge.villagra,carlos.gonzalez,teresa.depedro, ricardo.garcia}@car.upm-csic.es

Abstract. This paper presents a central station controlling the traffic flow of an intersection. In the proposed scenario autonomously driven and manually driven vehicles are mixed. The objective is to regulate both types of vehicles. Autonomously driven ones are controlled via wireless LAN communications; the autonomous vehicles send their positions and wait for the permission to traverse the intersection. The manually driven cars are detected in certain positions and controlled using the traffic lights. This paper presents the main idea implementation and shows the initial tests. After the discussion of the test results, some alternatives and future work lines are also exposed.

Keywords: ITS (Intelligent Transportation Systems), Safe Intersections, V2I (Vehicle to Infrastructure) and I2V Communications.

1 Introduction

The idea of using sensors to regulate the cycle time of a traffic light is starting to be used by the industry, especially in low traffic conditions. This work tries to go beyond this idea and use the perception capacity of the technology to build smart traffic lights. On our research group previous works we have achieved safe control an intersections by leaving each autonomous cars to take their own decisions [1][2]. Autonomous vehicles able to communicate each other, can share their positions, speeds, and turn intentions and use this information to determine the right of way. But with manually driven cars, and even with mixed traffic, the only way to coordinate the vehicles at an intersection is using traffic lights.

Nowadays the actual solution to control the traffic flow in an intersection is based in the cycle time of the traffic lights. This cycle times depends on a timetable. But other solutions are also available for the industry now; the cycle time of the traffic lights can be modified based on sensor inputs. The proposed idea is to use "intelligent" algorithms to directly control the traffic lights and optimize the traffic flow of the intersection.

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2 System Deployment

The aim of the control program is to regulate the intersection where autonomous and manually driven cars are mixed. To achieve this goal a computer has been placed near the traffic light regulator and acts as central station.

The central station has access to a GPS (Global Positioning System) base station and also grants the differential correction to the autonomous vehicles involve. So, using the same Wi-Fi network used to send the differential correction to the vehicles, the central station receives the position of all the autonomous vehicles that travels near the intersection. This communications channel is also used to send the intersection traverse permission to the vehicles.

The manually driven vehicles are detected using ZigBee sensors. Other sensor has been also tested, like laser or ultrasonic sensors, and will replace the Zigbee sensors in future implementations. To send the orders to these vehicles, the central station uses the traffic lights. The permission to traverse the intersection is given by a green traffic light.

Without the use of artificial vision (we are working now in car turn lights detection), the central station can only operate in two modes. The first one, that will operate in high traffic density cases, uses the cycle times following a timetable. The second one, used in low traffic density cases, turns the traffic lights to green when a vehicle approaches and no vehicle obstructs the path.

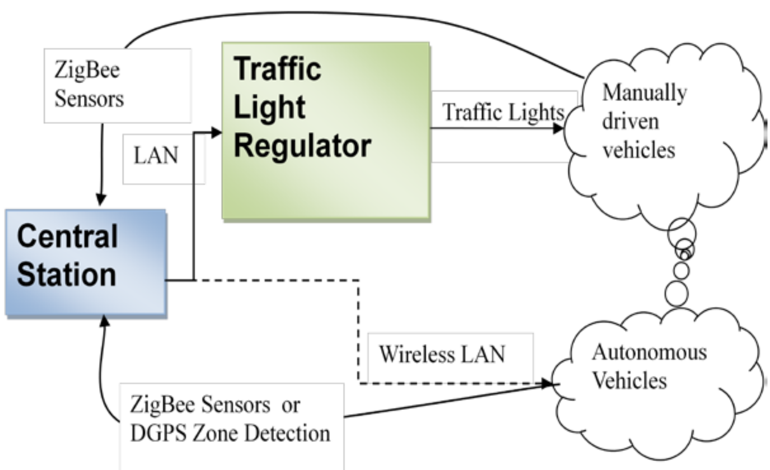

Fig. 1. System scheme: The central station get as inputs the positions of the manually and autonomously driven cars via the ZigBee sensors or the DGPS zone detections. And it sends as outputs orders directly to the vehicles via Wireless LAN or it modifies the traffic lights sending orders to the traffic light regulator via Local Area Network.

2.1 ZigBee Sensors

ZigBee is a specification for communication protocols. Its motes are used for radio-frequency (RF) applications that needs low data rate, long battery life and secure networking. These motes can use several sensors, like light, sound, temperature or magnetic sensors. In this case we have chosen to use light sensors to detect the vehicles approaching. Detection tests are shown in the next subsection.

Fig. 2. ZigBee mote

2.2 ZigBee Tests

Several tests have been made to select the best combination of the mote sensors that will permit the vehicles detection. As is shown in the figure 3, the only appreciable change, when the vehicle drive above the sensor, is shown in the light sensor. So, the mote light sensor is used to detect the presence of the vehicles.

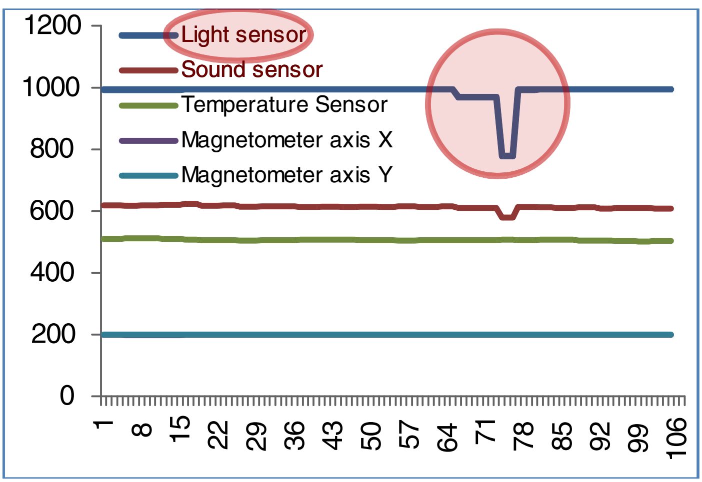

Fig. 3. Vehicle detection test: This experiment is used to choose the sensor to detect the vehicles

Once the light sensor has been selected, two ZigBee motes were deployed before each traffic light at the intersection. The setup can be seen in figure 4 left. With this setup, we started a set of experiments trying to determine at which speed the light

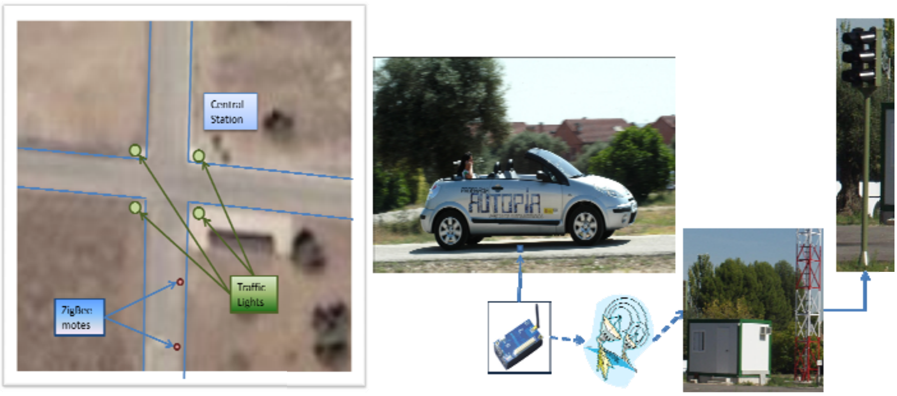

Fig. 4. Sensor test layout. This figure shows the placement of the ZigBee motes in the intersection *(left)* and the schema of the vehicle detection, and actuation over the traffic lights *(right)*.

sensors of the motes where not reliable enough. At 36 km/h, one of the two sensors was not able to detect the vehicle.

The experiments (figure 5) show a drastic reduction of the light intensity variation when the vehicle speed is 36km/h instead of 12km/h. As the vehicles that are arriving to an intersection reduce its speeds, the light intensity sensors of the ZigBee motes are good enough for this application.

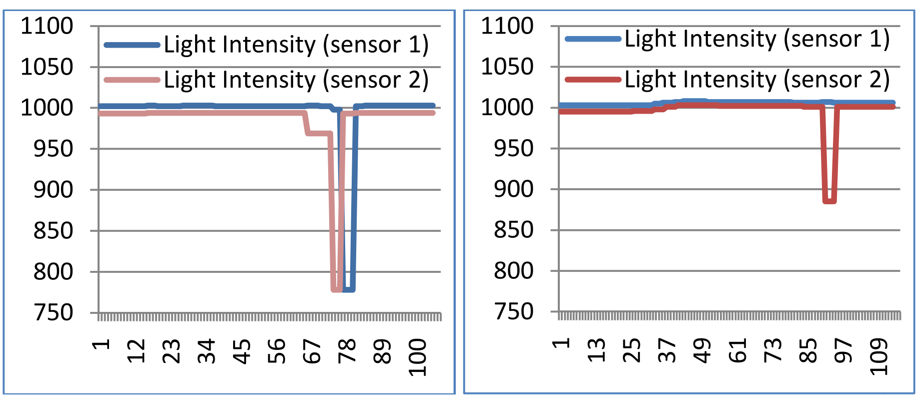

Fig. 5. The light intensity of both sensors decrease more than 200 cd when the vehicle goes above the sensor at 12km/h (*left figure*). When de vehicle goes at a higher speed, 35 km/h, the variation of light intensity detected is only 100 cd for the second sensor, and zero for the first sensor (*right figure*).

Some tests have been done with laser (DT50) and ultrasound sensors to replace the ZigBee motes. ZigBee motes are very cheap, there is no need of wires and work together in a mesh distribution. But they must be placed in the road, so they can be easily broken, the batteries and light sensors are needed to be replaced from time to time, and they have a very low sense rate (2Hz), so the vehicle can be undetected at high speeds. On the other hand, the laser sensors (DT50) are very robust and can be placed outside the road, they are designed to work outdoors, so they need a very low maintenance, and their sense rate is very high (50 Hz). Their main drawbacks are the price, and the need of wires and data acquisition cards.

3 Actuation: Traffic Lights and Autonomous Vehicles Orders

The last step is to send orders to the vehicles. The central station connects with the traffic regulator and changes the traffic lights under direct regulation regime to control the flow of manually driven vehicles. It also orders the autonomous vehicles to stop at a given position and stay there until new orders. This second step to achieve traffic regulation in the intersection is highly dependent on communications, but it still being secure because the autonomous vehicles needs to receive a permission to traverse the intersection.

3.1 Control Program

A control program has been made to monitorize the light intensity measurements of both motes, compared with ambient light. When a vehicle arriving to the intersection is detected, and there is no other car at the intersection (a timer is set to ensure that the previous car has had time enough to leave the intersection), the control program orders traffic lights regulator to change the lights via TCP communications.

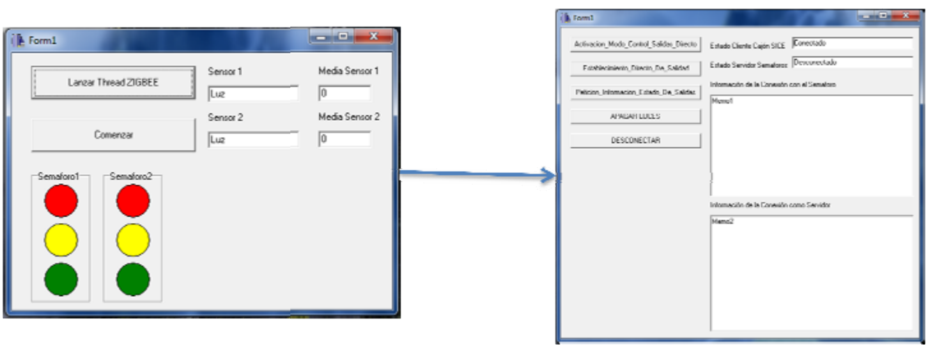

Fig. 6. The control program (*left*) set the traffic light to green or red depending on the vehicles detected. The traffic lights regulator is modified via an interface program (*right*).

The control program operates by pairs, it is the simplest way. Once a vehicle is detected in a lane, and there is no other vehicle in the right angle of that lane, the traffic lights of that lane and its opposite one are set to green, and the traffic lights of the right angle and left angle of that lane are set to red.

Autonomous vehicles are treated in the same way, if the traffic light of the lane where the vehicle is driving is set to green a message with the permission to traverse the intersection is sent to the autonomous vehicle. If the traffic light of the lane where the vehicle is driving is set to red, there is no need to send him a message denying the permission, but it still being sent for passenger's convenience.

4 Future Work

The replacement of ZigBee mote sensors with laser sensors is expected to highly improve the reliability of the detection part of the system. Initial tests made with laser sensors demonstrate high precision and reliability, even with black vehicles driving at high speeds (60 km/h).

Improvements in the actuation over the traffic light regulator are also planned. The direct traffic light modification is unsafe. Time intervals in which all traffic lights are red are needed to ensure the safety of the intersection. So, a routine to change traffic lights will be implemented.

To improve the logic of the system [3], it is planned to add cameras to the intersection. Artificial vision techniques will allow the system to know the turn intention of the vehicles and optimize middle traffic flow management. And, by adding cameras to the autonomous vehicles, the system will be able to send orders to the autonomous cars via traffic lights.

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