A CONFLICT-AVOIDING, ARTIFICIAL VISION BASED, INTELLIGENT TRAFFIC LIGHT CONTROLLER

Cristina Conde (1), Jorge Pérez (1), Pedro González (1), Jesús Silva (1), Enrique Cabello (1), Jesús Monclús (2) and Tomás Santa Cecilia (2)

(1) Universidad Rey Juan Carlos
ESCET
C/ Tulipán S/N
28933 Móstoles (Spain)

(2) RACE
C/ Isaac Newton 4
28760 Tres Cantos (Madrid)

SUMMARY

This paper presents an on-going research focused on providing artificial intelligence to a traffic light controller. RACE intends to use this intelligent traffic light in its small educative traffic safety village, in which students exercise practices using traffic signs (vertical and horizontal) and traffic lights. One intersection in this village is controlled by traffic lights and the University Rey Juan Carlos group is designing an artificial vision system to control it. Control will be done with two CCD cameras and an automaton. One computer will process the images and provide orders to the automaton (therefore to the traffic light). One CCD will control vehicle speed and the other will be dedicated to pedestrians. Use of computer and cameras will result in an adaptive control, in which time and sequence of lights will depend on the real conditions of zebra crossing. In this stage of the control, risky situations will be avoided. Control will be done to give enough time for pedestrian and to enforce vehicles to moderate and limit speed. Several sequences of lights will be implemented and each one will be dedicated to avoid specific situations: pedestrian in zebra crossing, excessive vehicle speed, etc. System will be tested in real conditions in RACE premises, with pedestrian and vehicles (in this case: bicycles). Feedback obtained in this test will be valuable to improve the system and to design a full-scale experiment in an urban environment. Also, the system will be fully parameterized, so it is possible to change values and to observe any effects on traffic conditions or in driver or pedestrian behavior.

INTRODUCTION

According to the European Transport Safety Council (ETSC) the transportation mode in between 15 and 30% of all trips in Europe is walking [1]. In Spain, and in large cities, one out of six surveyed Spaniards walked to their destinations in the year 2000, according to a telephone survey conducted by the Royal Automobile Club of Spain [2]. Walking is recognized as a healthy exercise with almost non-existing negative side effects, but when it comes to road traffic and on a distance basis, walking is approximately ten times more dangerous than travelling in a passenger car [3].

In the European Union 5,911 pedestrians died in 2000, 898 of them in Spain. This is the second highest figure in the EU, surpassed only by Germany, country with a population more than twice the Spanish one [4]. In 2001 there was a substantial reduction in the number of fatally injured pedestrians in Spain: traffic crashes originated 846 pedestrians fatalities (469 in rural areas and 377 in urban areas), a 5.8% reduction. These values represent the 15.5 and 15.3 percent of the total number of traffic fatalities in Spain in rural and urban areas respectively. Slightly over one half of all killed pedestrians died on rural areas in 2000: 451 fatalities in non built up areas and 447 fatalities in urban areas [5]. During 2001, the percentage of fatalities in rural areas increased up to a 55.4 percent.

In 2001, there were almost 55,000 urban traffic accidents in Spain with 75,000 injured road users (974 of which died). As mentioned before, 377 of them were pedestrians involved in run over crashes. Usually, it is thought that accidents in urban areas are not very important, but data shows the opposite. In 2002, from January to June there were 187 pedestrian fatalities in run overs in Spain as shown in the following table (shown by autonomic region).

PEDEDESTRIAN DIED BY RUN OVER		
		Data from January to June, 2002
Autonomic Region	**Accidents**	**Deads**
Andalucía	36	36
Galicia	22	23
Valencia	20	20
Cataluña	17	17
Castilla y León	14	14
Madrid	13	13
Castilla la Mancha	12	12
Asturias	10	10
Aragón	8	8
Baleares	8	8
Extremadura	6	7
País Vasco	6	6
Canarias	5	5
Murcia	4	4
Cantabria	3	2
La Rioja	3	2
TOTAL	**187**	**187**
Source: Dirección General de Tráfico and Instituto Nacional De Estadística		

The police-based crash reporting system attributes non-compliance with at least one of the Spanish traffic (safety) rules in the vast majority of the cases (in 81% of the cases in rural areas and in 63% of the cases in urban areas during 2000; in 81% in rural areas and in 64 % in urban areas during 2001). On the other hand, only 42 of the 898 pedestrians who died in 2000 in Spain were believed to have failed to obey the traffic light (2 in rural areas and 40 in urban areas). In 2001, the total number of pedestrians not obeying the traffic light was 33 (30 in cities and 3 in non built-up roads). The number of pedestrians being killed in traffic light-controlled intersections that were crossing with a green light is not known at this stage. In a similar way, it is also unknown the number of casualties that could have been prevented should the pedestrian have safely crossed the road or street at a traffic-light regulated intersection. The Spanish General Directorate for Traffic concluded, after analyzing in detail 300 pedestrian crashes in rural areas, that the pedestrian plays an active contributing role if 70% of the cases, while the driver is the main contributing actor in 50% of the cases.

The Spanish magazine Consumer [6] supervised during 4 days (9-14 April 2003) 14 points (8 traffic lights and 6 zebra crossings) in 13 Spanish cities. More than 33,000 pedestrian and 43,000 cars were observed. Results are shown in the following tables.

	PEDESTRIAN INFRINGEMENTS			
	ZEBRA CROSSING WITH TRAFFIC LIGHTS		*ZEBRA CROSSING WITHOUT TRAFFIC LIGHTS*	
	Crossing with traffic light in red	Crossing with green traffic light but not across zebra crossing	Crossing across zebra crossing but without seeing cars	Crossing not across zebra crossing
San Sebastián	31%	33%	31%	29%
Vitoria	26%	13%	21%	19%
Pamplona	27%	15%	17%	20%
Madrid	32%	17%	9%	22%
Bilbao	23%	15%	10%	17%
Málaga	28%	8%	4%	19%
Castellón	21%	14%	7%	27%
Logroño	13%	6%	15%	16%
La Coruña	19%	17%	3%	25%
Barcelona	13%	19%	4%	21%
Alicante	13%	10%	2%	19%
Valencia	6%	34%	7%	35%
Murcia	4%	13%	6%	16%
Average	**20%**	**16%**	**11%**	**22%**

	DRIVERS INFRINGEMENTS		
	Crossing with yellow or red traffic light	Crossing with pedestrian near or in zebra crossing	Car on the zebra crossing when stopped
San Sebastián	7%	8%	13%
Vitoria	12%	56%	3%
Pamplona	10%	21%	22%
Madrid	8%	40%	11%
Bilbao	8%	20%	10%
Málaga	7%	69%	7%
Castellón	4%	42%	1%
Logroño	28%	12%	8%
La Coruña	4%	41%	9%
Barcelona	13%	69%	6%
Alicante	4%	37%	5%
Valencia	4%	28%	4%
Murcia	2%	64%	5%
Average	**9%**	**39%**	**8%**

The promotion of the use of traffic light controlled crossings, when available, is believed to have a substantial positive effect in the reduction of vehicle-pedestrian conflicts. But in order to guarantee safety in a traffic light regulated intersection, both the pedestrians and the drivers must comply with all traffic rules. Therefore, road users should be encouraged to take advantage of traffic lights, and to comply with traffic rules. Besides fines and other penalties, a safe system can be promoted by a design that responds to user's expectations in the all necessary ways: waiting time is reduced to a minimum, duration of green light is adapted to the needs of the users... Users waiting too much time or not having enough time to cross the intersection during the green light may loose confidence in the system and become more prone to not safely use traffic light controlled crossings. Dynamic control of traffic lights has been traditionally oriented toward an optimization of traffic capacity, and safety of the system has been simply assumed, blaming the user in case this "perfect" system were not used as intended. No special "advanced safety" features have been implemented in the traffic light controller and from a safety point of view, the design of a traffic light has not experienced any substantial improvement in the last 75 years.

Eliminado: -

Different initiatives have been essayed with diverse degrees of success: pedestrian activated traffic lights, displays with waiting and crossing remaining times… Even with all them, discipline levels are very unsatisfactory in many instances. The authors of this article studied one "double" intersection where pedestrians were forced to consecutively cross two adjacent traffic lights in July 2003 in the city of Madrid and found that only 50% of the 155 observed pedestrians crossed *one of the two* intersections during the green light; only one pedestrian waited for the green light in *both* traffic lights. This non-compliance percentage is substantially larger than the one reported in Consumer magazine, circumstance partially explained by the fact that the intersection selected for RACE's observation largely fails to match the average pedestrian expectations: reasonable waiting times, synchronized lights for pedestrian...

The Royal Automobile Club of Spain plays an active role in the promotion of traffic safety in Spain. Though its main focus points at passenger car safety and individual mobility, the interaction between road vehicles and other modes of transport, as well as the safe interaction between the driver and other road users fall directly within RACE's more general objectives. Complementary, the Facial Recognition and Artificial Vision group at Universidad Rey Juan Carlos in Madrid has been involved in pedestrian behaviour analysis by means of artificial vision since 1998. Both institutions decided in 2002 to join efforts and explore new and innovative ways of improving the user-friendliness of the human-machine interface in intersections regulated by traffic lights.

Alongside the following sections, this article describes the user-centered logic, design constraints and prototype details of an "artificial vision controlled intelligent traffic light" which is believed to improve users behaviour in the neighbourhood of intersections.

STATE OF THE ART

In recent years, computer vision systems has been applied in traffic systems. Initial experiments developed in 1980 and 1990 put the emphasis in cameras placed near the road or in city streets but always in human supervised scenarios, with operators seeing the images. Gradually computer vision systems were broadly considered and impelled in two aspects. First, computer vision systems were widely placed in more positions, such as tunnels and other places related to automotive world such as streets, highways, etc. Second, computer vision system were evolving and more complex techniques start to help human supervision, such as license plate recognition, counting of cars, detection and tracking of cars, etc. In the references [7][8][9][10] it is possible to find these applications. Finally, it is important to mention one of the leading companies in the application of on-board computer vision system: DaimlerChrysler [11].

SYSTEM DESCRIPTION

System is shown in Figure 1, two cameras are focused in the zebra crossing, one looking to pedestrians and the other to the cars. Both cameras send images to a standard computer (in the future it could be replaced by one black-box). The computer processes images and obtain information about the presence of pedestrians and cars. Several working modes are implemented, if there is pedestrians waiting and no cars, computer send a signal to an automaton and the traffic light is changed, allowing pedestrians to cross and thus eliminating unnecessary waiting time for pedestrian. Also, if pedestrians are waiting and cars appears with high speed it is possible to send an extended warning yellow signal to cars, giving more time to stop. All transitions between working modes are done in a safely way.

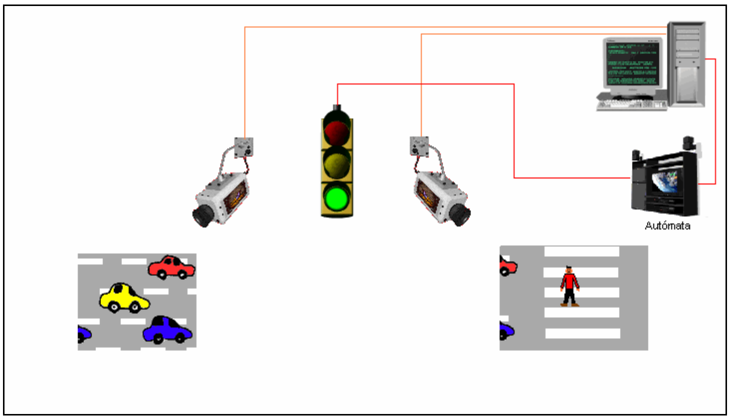

Figure 1. Schematic representation of the system

Algorithm is split in different parts, and will be briefly explained. A high level scheme of the algorithm is shown in Figure 2.

Initially, both cameras are loaded and parameters are set. This initial phase is done automatically when the system is on. Then, images are acquired and processed in real time. Two different threads are maintained in the computer, one take into account images acquired by car's camera and the other processes pedestrian's camera. Both images used the same algorithms and in the same sequence but objects processed by one camera are supposed to be cars and objects processed by the others are supposed pedestrians.

To obtain the objects that have been moved, background subtraction is performed [12]. Background is dynamically computed to cope with illumination changes during day and night. As cameras are firmly placed in the traffic light, it is possible to obtain a precise "background image" using several images. To compute this "background image" several images are taken in an array, the average or the mode of every pixel gray level in several images forms this "background image". The difference between actual image and the background are the objects moving in the scene. To finish this part, a noise reduction filter is applied, so small pixel variations are eliminated.

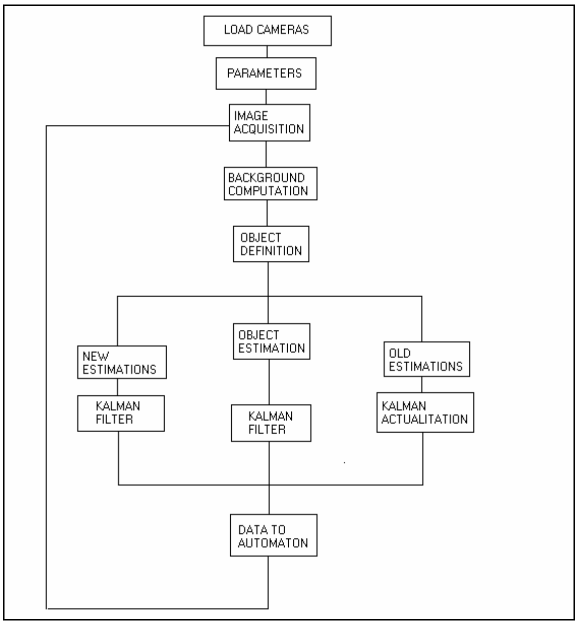

Figure 2. High level scheme of the algorithm.

Once these moving objects have been extracted, they are labeled and grouped. In this stage is also possible to classify each object as vehicle or pedestrian. In this stage individual pixels are grouped and a label is assigned to the set of pixels. This stage could be understand as the start of the "high level" computer vision algorithms. Till now, algorithms were related with images as arrays of pixels; now, we have a label such as "pedestrian number 1" or "vehicle number 5" to assign and to work with them.

Next step is to predict the movement of the different objects in the next frame and to check if the working mode of the traffic light has to be changed or not. A Kalman Filter [13] is used as mathematical model to predict speed, acceleration and position.

Last step in the algorithm is to send commands to the automaton. The automaton controls traffic light, so data sent to automaton implies a change in the traffic light sequence. This is the most intelligence and critical part of the algorithm. First, pedestrians and drivers behavior has to be taken into account, avoiding waiting situations during long periods of time. Second, safe transitions has to be done between working modes, avoiding periods of time in which traffic lights changes very fast. The following tables explain the working modes selected and in which situations the transitions are made.

Mode 1	Vehicles	Green	Yellow	Red
	Pedestrians	Red	Red	Green
Mode 2	Vehicles	Yellow		
	Pedestrians	Red		
Mode 3	Vehicles	Red		
	Pedestrians	Yellow		
Mode 4	Vehicles	Yellow Green		
	Pedestrians	Red		

Working modes: Mode 1 is a cyclic repetition of three periods however modes 2, 3 and 4 are one repetitive period.

Explanation	**New mode**	**Reasons of the change**
Default mode	Mode 1 or Mode 2 (selected according with day/night)	
Pedestrian detection	Mode 3	Time out No more pedestrians
Vehicles with high speed	Mode 4	Time out
Continuously detection of vehicles with high speed	Mode 4	No vehicle detection
Computer vision system is not working	Mode 1 or Mode 2	Computer vision system start to work

Transition matrix between working modes.

EXPERIMENTS, RESULTS AND CONCLUSIONS

Once the system were build, a set of experiments were performed to test algorithms and the complete system. Initial test were performed in lab conditions, using radio guided vehicles and simulating the presence of pedestrians. Code optimisation and design decisions were tested. This initial test were performed in a controlled environments, light changes were not abrupt, movement was smooth and the number of objects was not very large.

Once satisfactory results were achieved in lab conditions, a set of beta test were done in RACE premises at Jarama race track (own by the Royal Automobile Club of Spain). This beta test were taken during May, June and July 2003. In these tests, cameras were placed in one traffic light and more than 20 children used the premises (see Figure 3). Half of the children drive bicycles and the others acts as pedestrians. System works well under real conditions and children behaviour do not were influenced by the presence of cameras. So, system could be also used to collect data about pedestrian and cars behaviour in zebra crossings in an automatic way. Beta tests has been performed only during day and with excellent visibility conditions. During autumn 2003 test will continue with changing weather conditions (rain, fog and so on).

Figure 3: Right, pedestrian crossing and left, cyclist as seen by the camera.

Once this phase of the project has been ended, our work is focused to test the system under extreme weather conditions, to integrate more traffic lights in the system and to complete the system with other kind of sensors such as push button, etc.

This project is a joint initiative between the Rey Juan Carlos University and the Royal Automobile Club of Spain aimed at testing computer vision algorithms and their capabilities in real situations and their applicability and usability in traffic conditions. Computer vision is now a mature technology suitable for being implemented and placed in real streets to control traffic conditions with real-time actual information. Also, these technologies contribute to the improvement of traffic safety and to safer cities, and our obligation is to research in this direction: developing technology that makes cities more comfortable and citizen centred.

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