Computer Vision Application: Real Time Smart Traffic Light

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Abstract. The design, development, construction and testing of an Artificial-Vision controlled Traffic-Light prototype has been carried out to rule and regulate intersections. Methods, algorithms and automatons have been built up with that purpose to provide the analysis of images and decisions making at real time. The aim has been the development of an intelligent traffic-light capable of capturing the presence or absence of vehicles, pedestrians and their particular situations defined by their trajectories. Besides the above mentioned properties we have to point out the adaptation to the precise characteristics of each crossing, as its geometry, the required equipment, etc. The project has been supervised by RACE, world wide known as experts in road safety awareness, endowing the prototype with reliability and trust.

1 Introduction

A vast number of reports and statistics state the vulnerable role played by pedestrians in traffic accidents, especially in those who take place in surroundings considered safe by them. Walking is a healthy exercise with almost non-existing negative consequences except for those caused by road traffic. Walking under those circumstances is approximately ten times more dangerous than travelling as a passenger by car [1].

The availability of a wide database of accident causes is considered as one of the most important building blocks in the strategy for the development of intelligent integrated road safety systems [2]. For example, 15% of the total number of people killed on European roads are pedestrians, and 28% are vulnerable road users [3]. It is stated that most accidents take place in urban areas where serious or fatal injuries can be produced at relatively low speeds, particularly in the case of children [4].
Intersections are considered as a especially challenging problem for collision mitigation. UK statistics [5] indicate that 61% of personal injury accidents happen within 20 meters of a junction. In the USA, NHTSA [6] claims that 30% of crashes occur at intersections. The German Federal Statistical Office [7] identifies 86,497 accidents involving failure to observe priority or on entering the road. In Spain [8] the percentage of fatalities involving pedestrians represents the 15%. This suggests that feasible technical solutions reducing this type of accidents by 50% would save 6,000 – 7,000 lives per year only in Europe [2].

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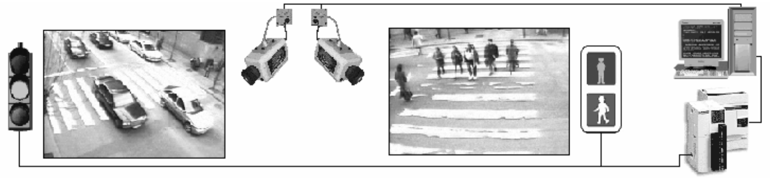

Fig. 1. In our prototype one camera focuses on the pedestrians and the other one on the vehicles. Images are then sent to the computer and as result a final working mode is sent to the automaton responsible for the traffic light switch.

A new trend in expansion is the application of computer vision techniques to traffic, in particular, for the intelligent control of traffic lights. Several factors such as number of pedestrians, situation of the crossing area, number of vehicles, etc., compete for the determination of the adequate colour of the light. This can have a substantial positive effect on the reduction of vehicle-pedestrian conflicts, especially when the system is optimized to meet the users' expectations: waiting time should be reduced to minimum, duration of green light should be adapted to the users' needs. The pre-programmed signal time allowed for pedestrians to cross a street is usually too short for some people, particularly the elderly and disabled ones, and exposes them to the oncoming traffic when the signal changes.

Despite many static cameras are being used in our cities (supermarkets, banks, underground stations, railway stations, etc.), their main commitment keeps being only to help operators make the best decision concerning security or to keep users informed of traffic fluency. Some computer vision applications have already reached the great public, as the on-board systems by Daimler Chrysler [9, 10].

From both perspectives, static and moving cameras, different approaches have been taken to detect the presence of pedestrians, using patterns of motion and appearance [11], using texture analysis and geometric features of pedestrians [12], using speed and path characteristics through a Kalman filter [13], processing background image [14], measuring motion similarity [15], using a Support Vector Machine (SVM) in night vision [16], and using an SVM to make this detection in real-time [17].

The rest of this paper is organized as follows: Section 2 describes the technical setup for our experiments, while Section 3 explains the algorithm used. Section 4 summarizes our main results and conclusions.

2 Technical Setup

The system consists of two cameras situated at only one signal post placed at an intersection. One of them focuses on the pedestrian crossing while the other one focuses on the vehicles arriving grid, as seen in Figure 1. The prototype has been developed as to be carried out by a conventional PC.

Each camera is connected to a Matrox Meteor II capture card with a resolution of 320×240 pixels. The images are alternatively taken as both capture cards share the same data bus. The image acquisition and processing is fast enough to make decisions in real time about the traffic light.

Table 1. Analysis of the different situations that may occur during the system performance. The decision to be taken is also expressed, as the resulting final working mode that will be sent to the automaton.

Vehicles Camera: Vehicles Presence	Pedestrians Camera: Waiting Pedestrians	Pedestrians Camera: Crossing Pedestrians	Automaton Mode
Yes	No	No	3
Yes	Yes	No	1
No	Yes	No	2
Yes	Yes	Yes	1
No	Yes	Yes	2
Yes	No	Yes	2
No	No	Yes	2
No	No	No	1

A TWIDO programmable automaton, by Schneider Electric, is in charge of the traffic light control. The automaton and the PC are synchronized about the working modes for an adequate functioning. These modes vary according to the presence of pedestrians or approaching vehicles, as can be seen in Tables 1 and 2. Mode 1 is a three cyclic states transition, whereas Modes 2 and 3 consist of only one state, so that the weakest part can reach a safe region.

Table 2. Specifications of the three possible working modes of the automaton

Mode 1	Vehicles:	→ Green → Yellow → Red →
	Pedestrians:	→ Red → Red → Green →
Mode 2	Vehicles:	Red
	Pedestrians:	Green
Mode 3	Vehicles:	Green
	Pedestrians:	Red

3 Algorithm Description

As Figure 2 shows, two different types of approaches have been developed. Low level procedures are in charge of the initial treatment of images to obtain the moving objects. High level procedures are in charge of analysing the movement and therefore providing the system with crucial information like position and trajectory, to make the required decision. The system can be easily adapted to different conditions in the intersection, so that it can be used for almost any type of crossing.

The images of vehicles and pedestrians are processed independently, but in a similar way. First of all, in order to track the moving objects, a background subtraction is performed [14, 18], by means of a consecutive set of 10 images organized in a FIFO queue. The mode of every pixel grey level is used for the computation of a continuously updated background image. After the subtraction, only moving objects, which will be hereafter referred to as components, can be identified (see Figure 3, a – c).

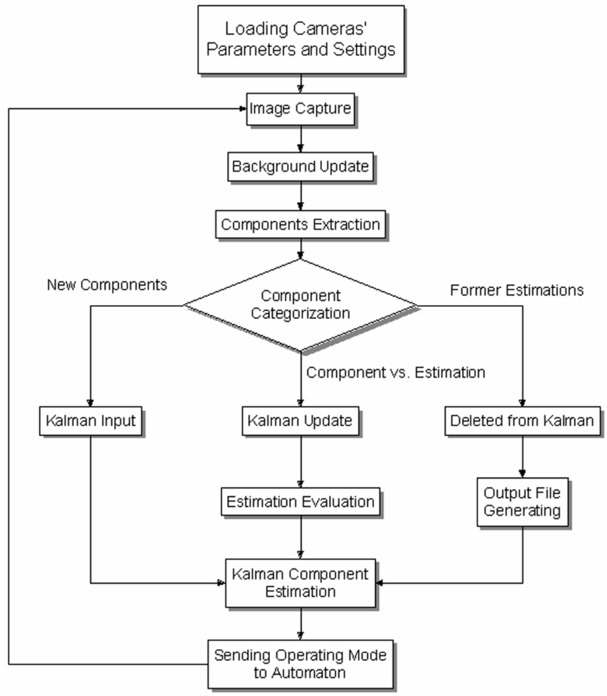

Fig. 2. The diagram shows the different steps that are taken during the algorithm

The calculation of the convex hull of the components has been established through a sequential labelling by checking each pixel in correspondence with its neighbours. A matricial labelling algorithm was put aside due to the high computational cost and the little improvement reached [19, 20]. Those components which do not reach a minimum amount of pixels are ignored, as they are considered as noise. Figure 3 (e – f) shows the subtracted image followed by the components labelled in a grey code image and the filtered result. Then each component is extracted as a separated image.

A Kalman filter is used for tracking moving objects, both vehicles and pedestrians. Initially developed for the prediction of random signals [21], it is able to estimate quantities as a function of time. An extended Kalman filter has been implemented [18, 22]. The algorithm adapts its model at each step to improve the movement estimation of the component. Position, velocity and values of the acceleration at different steps are used to predict the future object location. This allows us to track both vehicles and pedestrians in the scene. The Kalman filter can be adapted by means of a set of parameters that characterize the crossing area.

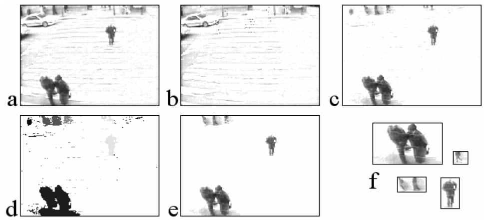

Fig 3. a. Source image taken at the pedestrian crossing. **b.** Background image computed with the mode of consecutive frames. **c.** Subtracted image with no background. **d.** Convex hull of every component labelled in a grey code. **e.** Final filtered image, without spurious components. **f.** Individual components to be tracked through the Kalman filter.

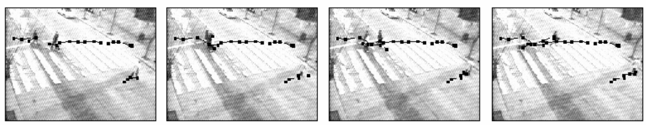

Fig. 4. Trajectories through time of three components. Consciousness and analysis of this trajectories in combination with the establishment of critical zones, let the system make the satisfactory decision in the traffic light control.

4 Results and Conclusions

Initial tests were developed in laboratory controlled conditions where light changes were not abrupt, movement was smooth and the number of objects was not very large.

Our algorithm was tested at the facilities of the Royal Automobile Club of Spain (RACE), which include an Educational Safety School at the Jarama Racecourse in Madrid. We have found that our system works well under real conditions, without influencing the presence of cameras in the behaviour of pedestrians and vehicles. After multiple tests done under RACE supervision, we can fairly state that the computer vision techniques used in this prototype are reliable and dependable to be introduced in our current daily life in roads and pedestrians crossings. Our system is always prepared, even in case of doubt, to make the choice for the weakest participant.

The prototype can also be modified to collect data on pedestrians' conducts, preferred crossing points or usual crossing paths. Behaviour of vehicles in the grid can be analysed, and an option to control density of traffic has been considered.

Our present aims focus on both, preparing the system to perform in an optimal way under extreme weather conditions and integrating several traffic lights and crossings under the control of the prototype.

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