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An expert fuzzy system for improving safety on pedestrian crossings by means of visual feedback

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ABSTRACT

Despite the continuous measures taken in large cities to improve road safety, pedestrian run-overs are still some of the main problems. In this paper an expert system is presented, whose aim is to reduce the number of run overs on pedestrian crossings with a luminous reinforcement system. An expert fuzzy system analyses the speed approaching vehicles travel at and the distance between them and pedestrians, in order to determine the degree of danger. This analysis is used to calculate the number of barriers that must be lit, from which position and their blinking frequency. Moreover, the system can recommend a speed to the driver so that he or she can return to a state of normality if this has been altered. The barriers light up according to how the driver behaves. If he or she slows down gradually on seeing a pedestrian, the barriers turn off at a similar pace. However, if the vehicle is approaching too fast, a path of light will be shown from the actual position of the pedestrian towards the vehicle. The number of barriers lit up and the blinking frequency will depend on the degree of danger the expert system estimates there is. In short, the light path shows if drivers are behaving suitably or not and tries to make him or her aware of it.

1. Introduction

As time goes by, people tend to group together in large cities, leaving the smaller settlements a country is made up of practically abandoned and overpopulating the cities. Better job opportunities or educational prospects, as well as the industrialization of agriculture or livestock, are some of the phenomenon which have caused this. If, the rising tendency in vehicle sales is added to this, and practically every household has one or two vehicles per home, then traffic congestion in these areas grows, and, therefore, there is a greater risk of accidents. All of this makes it almost obligatory to find solutions to improving road safety conditions which protect citizens.

According to the latest study by the Fundación Mutua Madrileña (Madrid Insurance Company, one of the most important insurance companies in Spain) on *road accidents and run-overs* (2013), **70% of all run-overs** that happen in the world occur on pedestrian crossings, and almost **45% of them at night**, in situations where there is little light, poor visibility, adverse weather conditions or dazzling produced by adjacent lights, amongst other things. Moreover, in this study, a series of important conclusions are presented which in themselves justify the need to create systems like those put forward herein. Some of the most noteworthy are the following:

- One in five traffic accidents which occur in Spain are run-overs, even though these are the most easily preventable road accident.
- Every year over 10,000 people are run over in Spain. Nearly 400 die and almost 3500 end up with serious injuries.
- A third of run-over victims are over 60 years old.
- Nine in ten run-overs occur in built-up areas.
- The main causes of run-overs are carelessness by pedestrians and speeding by motorists.
- 70% of run-overs are recorded when the pedestrian is crossing the street from one side to the other.
- According to gender, 6% more women are run over than men.
- Autumn is the season most prone to run-overs, with October being the month in which there are most cases of this.

From all these conclusions, it can be said that run-overs are mainly due to drivers being unaware of pedestrians, due to **poor visibility** or **speeding**. Therefore, with the help of new technologies which we can enjoy nowadays, a system capable of mitigating the effects of this poor luminosity and warning drivers about pedestrians crossing the street, will reduce the number of accidents to a great degree.

The solution we set out in this paper seeks to avoid both danger situations. Firstly, the path there is between the driver and the pedestrian is better lit, in such a way that it makes the driver focus on the place

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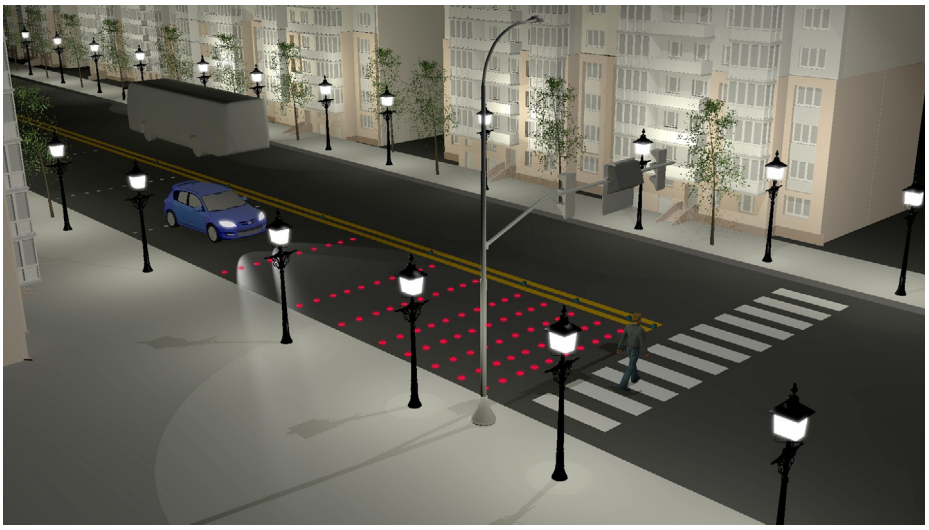

Fig. 1. Virtual scene which represents the proposal made in this paper.

where the pedestrian is. Secondly, the number of luminous barriers lit shows the degree of danger there is and the risk of a run-over. The more barriers are lit and the longer the path, the greater the risk. In this way, the driver will be able to perceive rapidly if his or her behaviour does not comply with traffic rules and take action to remedy this. If the vehicle speed is normal and is in keeping with traffic rules, the barriers will not be lit. However, the greater the speed, the greater the number of barriers will be lit between the vehicle and pedestrian. Fig. 1 shows a virtual scene which represents our proposal.

Therefore, an expert system is set out which is capable of detecting if there are vehicles and pedestrians, the speed at which they are travelling and how these evolve according to how the driver reacts. All this behaviour must be reflected in the control (lighting up and turning off) of the intelligent luminous barriers. In short, we propose a system which is intended to control the normality of an environment in which there is the risk of a run-over. When this normality changes due to the inappropriate behaviour of a driver, the system tries to influence him or her to go back to the normal state desired.

The rest of this article is organized in the following way: in Section 2, there is a study into the state of knowledge by looking at other previous works connected with the same topic. This study has enabled us to gain an in depth appreciation of the problem we are dealing with and, in this way, set out our own solution. In Section 3, there is an in-depth description of the system put forward. Both the components that it is made up of and their behaviour in different situations are given. Below, Section 4 shows how the system has been tested and the results obtained. These results have been truly satisfactory and prove that the solution set out is appropriate for the problem shown. Finally, the article ends with conclusions.

2. Previous work

In the context of this paper, a pedestrian can be defined as any person who is walking, running or standing in any situation resulting in an accident in which there is a second item: a motor vehicle. Pedestrian are an extremely vulnerable group from the point of view of traffic accidents, as they do not have any kind of protection mechanism if they collide with a vehicle. This premise, together with the fact that in urban settings vehicles share a physical space with pedestrians, means there is a need to continuously work on designing solutions for improving safety. To give a clear example of this problem in a specific setting, it is interesting to reflect on real figures and to extend the study commented on in the first section to other countries outside Europe.

Table 1
Total number of deaths and pedestrian deaths in traffic accidents in the United States, 2004–2013.

Year	Total deaths	Pedestrian deaths	Percentage of total
2004	42,836	4675	11%
2005	43,510	4892	11%
2006	42,708	4795	11%
2007	41,259	4699	11%
2008	37,423	4414	12%
2009	33,883	4109	12%
2010	32,999	4302	13%
2011	32,479	4457	14%
2012	33,782	4818	14%
2013	32,719	4735	14%

In 2013, the United States, one of the most populated countries in the world and one that has a high number of vehicles, a death toll of 4735 pedestrians was registered and the number of pedestrians estimated to have been injured in traffic accidents was 66,000, which was in keeping with a study by the Department of Transport carried out in February 2015 (U.S. Department of Transportation, 2015). Additionally, the total number of accidents which rose to 4653 resulted in one of more deaths in each of these accidents. On average, one pedestrian died every 2 h and one pedestrian was injured every 8 min as a result of a traffic accident. Table 1 shows the trend in the number of traffic accidents in which pedestrians were involved for the period 2004–2013 for the United States. As can be seen, there has been a decrease in the total number of deaths. Unfortunately the same cannot be said for the number of pedestrians killed. In other words, in this specific scenario the hypothesis described previously relative to the vulnerability of this group has been fulfilled.

This study from the United States Transport Department includes information in connection with environmental and time factors as regards the pedestrian deaths in 2013. For example, it is interesting to note that 73% of deaths occurred in built-up areas as opposed to 23% which occurred in rural areas. The place of death is also a key factor when improving the safety of pedestrians. In this setting, 69% of deaths were in places classified as non-intersectional, 20% in intersections and the remaining 11% in other places, in which pedestrian crossings are placed. From the point of view of light conditions, 72% of deaths occurred in dark or poor visibility situations.

There are other studies which are exclusively focused on pedestrian crossings, such as that discussed by R. Elvik et al. with respect to the city of Oslo (Norway), (Elvik, Sorensen, & Navestad, 2013) and which draw highly interesting conclusions based on an analysis of factors such as