Journal of Traffic and Transportation Engineering (English Edition) 2017; 4 (1): 3–13

Available online at www.sciencedirect.com

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journal homepage: www.elsevier.com/locate/jtte

Original Research Paper

# In-vehicle stereo vision system for identification of traffic conflicts between bus and pedestrian

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## HIGHLIGHTS

- A stereo-vision and GPS for traffic conflict investigation is presented for detecting conflicts between vehicle-pedestrian.
- An urban bus was equipped with a prototype of the system.
- A risk index is proposed to classify collision probability and severity using data collected by the system.

ARTICLE INFO

*Article history:*
Received 29 October 2015
Received in revised form
25 May 2016
Accepted 27 May 2016
Available online 4 January 2017

*Keywords:*
Traffic conflict
Stereo vision
GPS
Bus
Risk index

ABSTRACT

The traffic conflict technique (TCT) was developed as "surrogate measure of road safety" to identify near-crash events by using measures of the spatial and temporal proximity of road users. Traditionally applications of TCT focus on a specific site by the way of manually or automated supervision. Nowadays the development of in-vehicle (IV) technologies provides new opportunities for monitoring driver behavior and interaction with other road users directly into the traffic stream. In the paper a stereo vision and GPS system for traffic conflict investigation is presented for detecting conflicts between vehicle and pedestrian. The system is able to acquire geo-referenced sequences of stereo frames that are used to provide real time information related to conflict occurrence and severity. As case study, an urban bus was equipped with a prototype of the system and a trial in the city of Catania (Italy) was carried out analyzing conflicts with pedestrian crossing in front of the bus. Experimental results pointed out the potentialities of the system for collection of data that can be used to get suitable traffic conflict measures. Specifically, a risk index of the conflict between pedestrians and vehicles is proposed to classify collision probability and severity using data collected by the system. This information may be used to develop in-vehicle warning systems and urban network risk assessment.



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Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2016.05.007

## 1. Introduction

Improvement in road safety knowledge is associated with a better understanding of the link between road features and road users and their dynamic interactions observed directly on the road in the short time prior a collision. Nevertheless, given the variability and complexity of road users behaviors and performance, as well as the random and rare nature of crashes, challenges still remain in quantifying these relationships basing only on crash data.

In this framework, the traffic conflict technique (TCT) is a promising methodology of field observations to quantitatively describe the interactions between road users involved in a critical event for safety, not only in the occurrence of a crash, and the use of geo-referenced stereo sequences and tracking procedure constitutes an innovative tool in TCT applications. For this reason, in the context of a national research program on a new concept urban bus, a geo-referenced stereo system was developed to identify and analyze traffic conflicts between vehicle and pedestrians crossing in front of the bus. Such a system can support bus driver task in the event of a potential collision by the activation of real time warnings. Moreover, the conflict data can be stored for naturalistic studies of driver behavior during critical events (conflicts, near crashes, collisions). In urban area crash interactions between bus and pedestrian is one of the main sources of accidents involving a bus and cause of concerns for the transport agencies due to the high cost and social impact. Therefore, the market penetration of such equipment offers the interest of looking to a vehicle segment characterized by high investment cost and managed by a limited number of operators.

The field of application (i.e., intelligent transport system (ITS) for bus safety), the methodology (i.e., traffic conflict technique) and the novel equipment (i.e., stereo system with GPS) are presented in this paper together with a pilot implementation on the bus-pedestrian interaction to evaluate the effectiveness and potential use of the proposed system.

## 2. ITS for bus safety

European statistics shows that bus crashes account for only 1% of total road fatalities, but bus represents only the 0.35% of the overall motorized vehicles (ERF, 2010). Because of the low percentage of crashes involving buses and the assumption that public transport improves road safety by reducing the number of vehicles on the streets, public interest in bus safety is not as evident as for other types of vehicles (e.g., passenger cars, trucks, powered two wheels). Nevertheless, the introduction of new technologies, that can be easily and widely diffused in the bus market makes safety improvements challenging and of interest for the transport agencies as revealed by a pool among the operators (Cafiso et al., 2013a,b).

It is generally assumed that new technologies can support safety improvements. In particular, a great deal of attention has been paid to the effects of driver assistance systems on driver performance (Lin et al., 2008). However, challenges still remain in quantifying the effectiveness of these systems in terms of their impact on reliability, profitability, and safety (TRB, 2011). At the present time, despite the great interest showed by operators to equip new and old bus fleets, little information based on their effective operation under real traffic condition is available in order to relate their working parameters to unsafe events and to perform qualitative and quantitative warnings for the driver (Cafiso et al., 2013a,b).

Based on present experiences (Shankar et al., 2008), great emphasis is given to inside vehicle measurements monitoring driver performance and vehicle dynamics (e.g., braking, steering, pedal use, safety belt use, eye tracking, lane departures, lane position, hours of service, driver fatigue, driver alertness, turn signal use, and GPS coordinates). Video records are usually used to qualitatively analyze the outside vehicle environment (e.g., weather and light conditions, presence of other road users and conflicting vehicles). Less to no quantitative outside vehicle measures is usually acquired (e.g., distance of the opponent vehicles, obstacles or vulnerable road users). Due to the complexity in the correlation between the recordable data and the collision event, surrogate measures of safety provided by traffic conflict technique can be used to overcome this problem.

## 3. Surrogate measures of safety: traffic conflict techniques

The Heinrich Triangle theory (Heinrich, 1932) was founded on the casual relationship that no-injury accidents preceded minor injuries. The second basic idea of the Heinrich Triangle is that because near-accident events occur more frequently than accidents, their occurrence rate can be more reliably observed. Another advantage of this approach, with respect to traditional crash analyses, is its proactive evaluation (i.e., it is possible to identify the safety deficiencies prior to accident occurrences and to adopt preventive countermeasures).

The TCT is founded on the Heinrich Triangle theory, assuming that the appropriate traffic conflict (TC) factors can be defined as measures of near-crash events. A TC is defined as an observable situation in which two or more road users approach each other in space and time to such an extent that there is risk of collision if their movements remain unchanged (Hanowski et al., 2000; Hyden, 1987). Traffic conflict measures, such as time to collision (TTC), address the first condition of surrogate measures, namely the common factors that are shared with safety (Hayward, 1972). The shortest TTC illustrates the idea that events closer to the base of the triangle precede the events nearer to the top.

However, the limitations of the TC measures are due to the often unproven relationship between the surrogate events and the crash occurrence. Many researchers have broached this thorny subject, suggesting that validity problems were at least partially due to the quality and coverage of the accident data (Chin and Quek, 1997; Zheng et al., 2014) and reporting the need for validation in relation to the diagnostic qualities of the TCT (Hyden, 1987). Thus, other authors (Migletz et al., 1985) indicated that TC studies can produce estimates of crash occurrences that are as good as those based on crash data but require a significantly shorter period for data