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Recognition method of construction conflict based on driver's eye movement

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ABSTRACT

Drivers eye movement data in simulated construction conflicts at different speeds were collected and analyzed to find the relationship between the drivers' eye movement and the construction conflict. On the basis of the relationship between the drivers' eye movement and the construction conflict, the peak point of wavelet processed pupil diameter, the first point on the left side of the peak point and the first blink point after the peak point are selected as key points for locating construction conflict periods. On the basis of the key points and the GSA, a construction conflict recognition method so called the CCFRM is proposed. And the construction conflict recognition speed and location accuracy of the CCFRM are verified. The good performance of the CCFRM verified the feasibility of proposed key points in construction conflict recognition.

1. Introduction

The widely used theory of pointed out that the physio-psychological reaction characteristics of road users should be the basis of the road traffic design (Gregoriades and Mouskos, 2013; Reason, 2016; Fuller and Santos, 2002; Fu and Pei, 2012). However, current road safety evaluation technologies, especially the traffic conflict technique, do not evaluate from driver's psychological perspective.

The study of the relationship between stimuli and the eye movement provides a new direction for exploring traffic conflict indicators which can reflect driver's mental load: blinks do not occur randomly but rather, blink bursts follow high cognitive load or information processing (Van Opstal et al., 2016; Lee et al., 2015; Rubin et al., 2017; Ichikawa and Ohira, 2004);blinks are inhibited during information acquisition, and facilitated following the termination of such processing (Edmund et al., 2015; Mandel et al., 2014; Helokunnas, 2013; Anderson et al., 2013; Gao et al., 2013; Schleicher et al., 2008; Caffier et al., 2003); gaze data refers to the driver's intent, which is formed before the maneuver takes place rather than to driver's actual execution of the maneuver (Lethaus et al., 2013) resulting in a temporal benefit for gaze-based recognition; the pupil is larger under conditions of higher attention allocation, memory use, or interpretation of more difficult material and the pupil dilation persists if the demand is sustained (Marquart et al., 2015; Gilzenrat et al., 2010).

Neumann and Lipp studied effects of mental load on pupil diameter changes (Neumann and Lipp, 2002); Einhäuser et al. (2008) studied consciousness changes impact on the pupil diameter and analyzed physical factors which cause pupil diameter changes (Einhäuser et al., 2008); Steinhauer et al. (2004) analyzed effects of task difficulty on the pupil diameter in the neurological level (Steinhauer et al., 2004); Konstantopoulos et al. (2010) studied the eye movements of driving instructors and learner drivers while they drove three virtual routes that included day, night and rain routes in a driving simulator (Konstantopoulos et al., 2010); Smilek et al. (2010) assessed the relation between eye blinks and mind wandering (Smilek et al., 2010).

Road traffic conflicts can be divided into forward conflict, rear end conflict, cross conflict and construction conflict, and we only study the construction conflict (road users conflict with constructions in the road) (Luo and Zhou, 2001; Wang, 2008). The studies confirmed that cognitive and specific incentives can impact on the eye movement. However the researches did not study effects of traffic conflicts stimuli on driver's eye movement. We hypothesized that blink, gaze direction and pupil diameter have the correlation with the construction traffic conflict (Minkov et al., 2012; Ohira, 1996), and driver's eye movements can be used as indicators to recognize traffic conflicts. In this paper, drivers' eye movement data in simulated construction traffic conflict tests were collected, processed and analyzed. The traffic conflict definition based on eye movement was set, the corresponding recognition method was proposed, and the feasibility of the proposed method was analyzed.

2. Experimental design and procedure

Construction conflicts are simulated using driving simulator which can simulate vehicles, road environment and road constructions to control effects of the light intensity on the pupil diameter. The driving simulator consists of the seat, the gear-shift, the steering wheel and

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Fig. 1. Schematic diagram of the test scenarios.

Table 1
Blinks in conflict periods.

Speed	Test times	Blinked once before stop	Crashed without blink
20km/h	200	200	0
30km/h	200	200	0
40km/h	200	163	37
50km/h	200	51	149

pedals. China's Ministry of Public Security showed that in 2016, there were 260 million male drivers, accounting for 72.77%, and 97 million 380 thousand female drivers, accounting for 27.23%. The age distribution of men who meet the requirements we can count is mean age = 38 years, SD = 6, and the age distribution of women who meet the requirements we can count is mean age = 41 years, SD = 5. Therefore, 7 male drivers (mean age = 38 years, SD = 6) and 3 female drivers(mean age = 41 years, SD = 5) who have more than 10 years driving experience were randomly extracted according to distribution. The length of the two-line straight road is 208 m, the accelerating section is 200 m, and the distance from braking line to the construction is 8 m. The model of the simulated vehicle is VW Tiguan 1.4 TSI, and the simulated construction is a traffic cone. The schematic diagram of the test scenarios is shown in Fig. 1.

Firstly, participants were asked to look at the screen in the lab, and the average light intensities were adjusted to 370lx and 490lx. Secondly, participants were asked to drive from the starting line of the road at the speed of 20 km/h, 30 km/h, 40 km/h and 50 km/h separately, and free brake from the braking line. Tests were repeated 10 times by every participant in every light intensity. Participant's eye movement (blink, gaze direction and pupil diameter) were collected by Smart Eye Pro 5.7 eye tracking system at the sampling frequency of 60 Hz. Light intensity data near participants were synchronously collected by TES-1339R illuminometer with its PC client software. Test data were divided into group L (data collected in 370lx) and group H (data collected in 490lx) according to light intensities. When participants drove in 370lx, test data were collected and recorded as speed divided groups L-1 to L-5 accordingly. When participants drove in 490lx, test data were collected and recorded as speed divided groups H-1 to H-5 accordingly.

3. Analysis of the blink

The blink data show that, at the speed of 40 km/h and 50 km/h, if the vehicle hit the construction, there will be no blink in the conflict period. The blinks in conflict periods are shown in Table 1. It can be seen from Table 1 that if the vehicle did not hit the construction the probability of blinking is 100%.

The reasons of Table 1 might be as follows: drivers' mental load was increased due to the conflict, and in the conflict period, drivers paid attention to the distance between the vehicle and the construction, which means that drivers are in the processing of massive visual information acquisition. After the vehicle stopped, the drivers' mental load was decreased; drivers were distracted and visual information massive acquisition processing was completed. Independent literature suggests that blinks do not occur randomly (Ohira et al., 1998), but rather, blink bursts following high cognitive load (Siegle et al., 2008; Pedrotti et al., 2014) or information processing, possibly reflecting a release of resources used in stimulus-related cognition (Shi-gui and Zhou, 2003). In this paper, blink data reflect that blinks are inhibited during information acquisition, and are facilitated following the termination of such processing. The result is consistent with previous studies (Machhale et al., 2012).

4. Analysis of the gaze direction

The gaze direction changes are reflected by angles which are calculated by Smart Eye Pro5.7 collected adjacent sampling points' gaze directions. Driver's gaze directions collected by Smart Eye are expressed in the form of unit vectors, thus the gaze change angles can be calculated as following:

$$\alpha = \arccos(x_i x_{i+1}, y_i y_{i+1}, z_i z_{i+1}) \quad (1)$$

It is assumed that the ith gaze direction vector is (x_i, y_i, z_i), the $i + 1$th gaze direction vector is $(x_{i+1}, y_{i+1}, z_{i+1})$, driver's gaze change angle α can be calculated by Eq. (1).

The correlation between the conflicts and gaze angles was analyzed to determine the impact of conflicts on gaze angles. The conflict value in the conflict period is set as 0, and the conflict value of the stop moment is set as 1. One conflict and gaze angles of group H-2 is shown in Fig. 2. And the correlation between the conflicts and gaze change

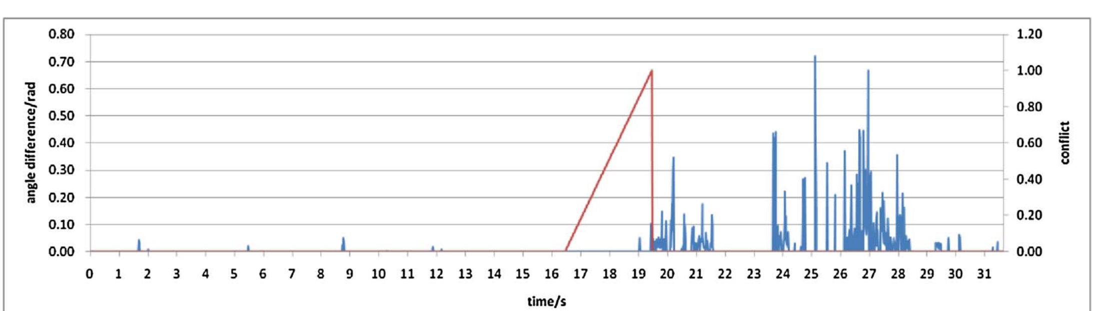

Fig. 2. One conflict and gaze angle difference of group H-2.