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Validated Throw Distance Method by Surveillance Video

Abstract Vehicle-pedestrian collision is one of the most frequent and most severe types of road accidents. The impact velocity is the most important factor in vehicle-pedestrian accident reconstruction, and it can be calculated by many theoretical or empirical methods including throw distance. The throw distance method needs to be validated by other methods for more credible. In this paper, a traffic accident was caught by surveillance video, and was employed to validate the throw distance method provided by *The Speed Technical Evaluation for Vehicles Involved in Representative Road Accidents* (GA/T 643-2006, China, 2006).The results showed that the impact velocity was calculated by throw distance (36.39 km/h) which is 22.01% lower than the video monitoring (46.66 km/h), which indicated that the vehicle speed calculated by throw distance was much lower than the real-world speed. Further studies are needed to modify the throw distance method by more evidences.

Keywords: Accident reconstruction; Vehicle–pedestrian accident; Vehicle speed; Throw distance; Surveillance video;

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1. Introduction

At present, the road traffic accident has become one of the most serious social hazards which the whole world faces together. Nearly 3,500 people die on the world's roads every day. Tens of millions of people are injured or disabled every year. Children, pedestrians, cyclists and the elderly are among the most vulnerable of road users [1]. China has consistently ranked as the country with high percentage of pedestrian fatality rates because of its mixed traffic and transportation ways [2]. According to the Road Traffic Accident Annual Census Report of China [3], more than 81,649 persons died in at least 327,209 accident cases in 2007, among which the pedestrian accounted for 25.85%, being the highest proportion of all traffic fatalities.

In vehicle–pedestrian accident reconstruction, the two most important objectives are to determine the impact position and the impact speed. The vehicle impact speed is the prior focus for accident investigators [2]. The impact speed can be calculated by many theoretical or empirical methods which have been used to calculate the impact speed and can be categorized by evidences required. The categories are the post-braking-distance [4], the throw distance [5–7], the vehicle damage [8–9] and the pedestrian injury [10–11]. Here, the throw distance represents as a method to calculate the impact speed according to the throw distance, and the throw distance methods has been employed in *The speed technical evaluation for vehicles involved in representative road accidents* in 2006.

The video surveillance system as an important safe surveillance in traffic and police has been widely used in security and other fields for its full and accurate information. Along with more surveillance cameras using, more traffic accidents have been caught. Cameras can record not only the process of a case, but also the details of a traffic accident, such as vehicles routes, vehicles speeds, pedestrian projection distances and so on that these pieces of information are based for appraising a traffic accident.

Throw distance methods are usually obtained by two ways that one by statistical analyzing the real traffic accidents data [7] and the other by computer simulation like the PC-Crash [12] or the Madymo pedestrian model [13]. Compared with the computer simulation, real traffic accidents data is more credible but has its confidence interval; the PC-Crash's pedestrians is a multi-rigid-body system only for simulation, so it is different from real traffic accidents and the results need to be validated by plentiful real cases. When a traffic accident is recorded by the video surveillance system, it could calculate vehicles speeds and the speeds would be exacted.

Sometimes, in order to make the vehicles speeds more credible, solutions of these methods are often used to validate each other. In this paper, it used a clear video from a traffic accident case, which was provided by *the State Key Laboratory of Vehicle NVH and Safety Technology (Chongqing, China)*. This case was a vehicle–pedestrian collision, in which it has calculated vehicles speeds by throw distance method and by the surveillance video. The purpose of this study was to validate throw distance method by the surveillance video.

2. Methods

2.1. A case study

A vehicle–pedestrian collision occurred on a flat road on sunny day, on October 17, 2011, in Chongqing. The process of the traffic accident could be observed clearly by video. Before the case, the suspected vehicle wanted to overtake another car, while at the

a b c

Fig.1 The traffic accident scenes.
(a, b, c: the positions of the white car at scenes)

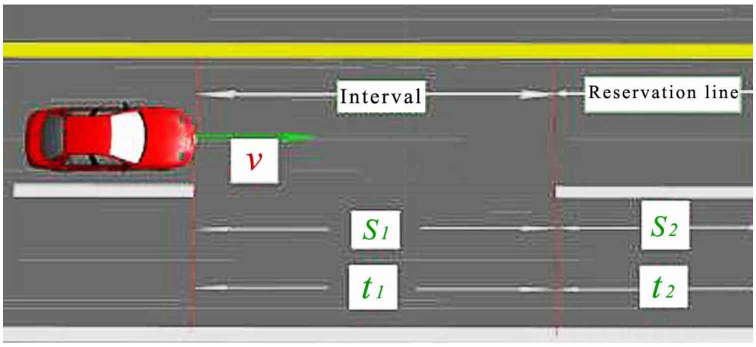

Fig. 2 A sketch for the vehicle speed calculating.

a b

Fig.3 The impact position and the rest position of pedestrian.

same time, a pedestrian was standing at the middle of the road. The driver braked at once, but the car still impacted the pedestrian. The pedestrian flied, landed and slid to the rest position, and the car braked until stopped.

2.2. Surveillance video

The video surveillance system can clearly record the pedestrian–vehicle accident information. According to $v = \Delta s / \Delta t$ (where v is the speed, Δs is the distance, and Δt is the time.), the movement of objects at average speed was the displacement in a unit time. In dynamic image sequences, Δt may be calculated directly by the export of the frame rate. It can analyze the video frame by frame for choosing reference distance, determining the time of vehicles through the reference, measuring the driving distance of vehicles in this time, and calculating the vehicles speeds finally. The points from the surveillance video method are accurate reference distances and the number of frames.

In this accident, the white car positions were various in different scenes (Fig.1)

In video, car positions are corresponding with the time. A reservation line was employed as the mark. The car was driven pass a reservation line and an interval in this pedestrian–vehicle accident (Fig.2). The interval was the "a-b" phase, the reservation line was the "b-c" phase, and s_1, s_2, t_1 and t_2 were the distances and the driving times for the reservation line and for the interval, respectively.

It assumed the car was decelerated uniformly with a frictional drag coefficient a on a dry and flat road. According to Newton's laws, the car speed can be calculated by Eqs. (1), (2) and (3)

$$v_a = v_b + at_1 = v_c + a(t_1 + t_2) \quad (1)$$

$$v_a^2 - v_b^2 = 2as_1 \quad (2)$$

$$v_b^2 - v_c^2 = 2as_2 \quad (3)$$

Where v_a, v_b and v_c are the car speeds (m/s) respectively at points of a, b and c. In this phase, the car speed can be calculated at every frame.

2.3. Throw distance

The throw distance was defined from the impact position to the rest position of pedestrian. The impact position and the rest position of pedestrian were in scenes (Fig.3).

The surveillance video recorded all details for a traffic accident. It could calculate the speed and the time of the vehicle and the throw distance of the pedestrian. The impact speed of the vehicle can be calculated using Eq.(4)

$$v = \sqrt{2g} \times \varphi \times \left(\sqrt{h + \frac{S_p}{\varphi}} - \sqrt{h} \right) \quad (4)$$

Where v is the impact speed (m/s) of vehicle, the sliding adhesion coefficient; the throw distance (m), h the height of the gravity center of the pedestrian (m) and m/s^2.

The height of the pedestrian's gravity center can be calculated by Eq.(5).

$$S_p = 5H / 9 \quad (5)$$

Where H is the height (m) of the pedestrian.

When the throw distance and the height of the pedestrian were obtained, the vehicle impact speed could be calculated by Eqs. (4) and (5).

3. Results

3.1. Calculating the vehicle speed by the surveillance video

In this case, a reservation line was employed as the mark. The frequency of the surveillance camera was 25 frames per second. The distance of reservation line length (s_1) was 6.0 m and respectively the interval (s_2) was 9.0 m; The car driven pass the reservation line and the interval, which respectively consumed 14 and 11 frames. So, the distances and the driving times of the reservation line (t_1) and the interval (t_2) were 0.56 s and 0.44 s, respectively. According to Eqs. (1),

(2) and (3), the car speed and the decelerated rate can be calculated as

v_a=17.44m/s=62.78km/h (6)

v_b=14.71m/s=52.96km/h (7)

v_c=12.57m/s=45.25km/h (8)

a=4.87m/s2 (9)

v_a, v_b and v_c were all not the impact speed of car (v). The impact point was 2 fremes (t=0.08 s) before the point c. The uniformly decelerated rate of the car was 4.87 m/s2. The impact speed can be calculated as

$$v = v_c + at$$

$$= (12.57 + 4.87*0.08)\ \text{m/s} = 12.96\ \text{m/s} = 46.66\ \text{km/h} \quad (10)$$

3.2. Calculating the vehicle speed by the throw distance

In this case, the pedestrian was a 56 years old female with the height of 1.50 m. The height of the pedestrian's gravity center (h) could be calculated by Eq. (5)

$$h = 0.8333\text{m} \quad (11)$$

Because the impact point was 2 frames before the point c that the distance (x) between the impact point and the point c could be calculated by Eq. (12)

$$v^2 - v_c^2 = 2ax \quad (12)$$

According to Eq. (12),

$$x = 1.02\text{m} \quad (13)$$

another part of the throw distance of the pedestrian was 15m. So,

$$S_p = 1.02\ \text{m} + 15\ \text{m} = 16.02\ \text{m} \quad (14)$$

According to *The Speed Technical Evaluation for Vehicles Involved in Representative Road Accidents* (GA/T 643-2006, China, 2006), the friction coefficient (φ) between the woman pedestrian and the dry flat road was 0.44, that the car speed (v) could be obtained via Eqs. (4), (11) and (14) as

$$v = 10.11\ \text{m/s} = 36.39\ \text{km/h} \quad (15)$$

3.3. The relationship between the throw distance and the surveillance video

The results showed that the speed of the car was calculated 22.01% lower by the throw distance (36.39km/h) than by the surveillance video (46.66km/h).

In the previous demonstration, Fugger 2000 represented the solution of Fugger's method [14], which was

$$v = 8.364 * S_p^{0.6046} \quad (16)$$

Where v was the vehicle impact speed (km/h).

Toor 2003 represented the solution of Toor's method [15], which was

$$v = 9.84 * S_p^{0.57} \quad (17)$$

The car speed (v) could be obtained via Eqs. (14) and (16) as v=44.75 km/h; and via Eqs. (14) and (17) as v=47.82 km/h. The impact velocity calculated by Fugger's method was lower (1.91 km/h) and higher (1.16 km/h) by Toor's method than by the monitoring video. Compared with the throw distance, Fugger's and Toor's results were closer to the surveillance video, with a spread averaging about ± 4.1%.

4. Discussions

In this study, it has provided the evidence that the vehicle speed calculated by the throw distance is much lower than the real speed. The impact velocity calculated by the throw distance (36.39km/h) is 10.27 km/h lower than by the surveillance video (46.66km/h) in this case.

The results are consistent with the previous reports. The current study has shown that the pedestrian pre-impact posture and velocity has a significant influence on pedestrian kinematics during vehicle-to-pedestrian impacts. Many models, both theoretical and empirical, have been developed over the last 30 years to reconstruct this type of impact, but not all of them yield accurate results, with a spread averaging about ± 10 km/h [16].

Additionally, the case has been employed validating Fugger's and Toor's methods which also based on the throw distance and whose results are closer to the surveillance video than the throw distance method provided by *The speed technical evaluation for vehicles involved in representative road accidents* in 2006. In other words, Fugger's and Toor's methods have higher accurateness.

5. Conclusions

Vehicles speeds are the most important parts of the vehicle-pedestrian accidents reconstruction. The method now more commonly used to determine vehicle speed involves the pedestrian projection distance, while the more traditional method by tyre brake marks is losing applicability because of the population of ABS braking systems on the road. From this study, a traffic accident has been caught by the surveillance video, and been employed to validate the throw distance methods provided by *The Speed Technical Evaluation for Vehicles Involved in Representative Road Accidents* (GA/T 643-2006, China, 2006). The results have shown that the impact velocity calculated by the throw distance is much lower than the real-world speed.

In this paper, there is only one traffic accident. It is not sufficient for identifying the speed of vehicle for not accurately calculated by the throw distance method. But it really is a proof and complication of the precious researches which should be helpful for modifying the throw distance method in future.

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