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Parameter Weight Analysis of Car Side Impact Accident Reconstruction

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Abstract

In order to improve the accuracy of car side collision accident reconstruction, a domestic accident case is taken as an example to reconstruct the accident through PC-CRASH and design the orthogonal experiment. Through experiments, the weight ranking of PC-CRASH side impact reconstruction is obtained. According to the weight of the parameters, the accident case is reconstructed again. The results show that the error between the reconstructed result and the actual accident result after the targeted adjustment of the parameter is significantly smaller than the error between the reconstruction result obtained from the unadjusted adjustment parameter and the actual accident result. Therefore, it is verified that the accident reconstruction according to the weighting of the affected parameters can improve the accuracy of the result of PC-CRASH accident reconstruction of the side collision of the car.

Subject Areas

Mechanical Engineering

Keywords

Side Collision, Parameter Weight Ordering, PC-CRASH Software, Orthogonal Experiment

1. Introduction

According to the statistics of the Traffic Management Bureau of the Ministry of Public Security of the People's Republic of China [1], as of the end of March 2017, China's motor car ownership exceeded 300 million, of which the car ownership exceeded 200 million for the first time. With the rapid development of the automobile industry, the road traffic accident rate in China has also remained high. The US fatal accident report indicates that 22% of motor car traffic accidents are caused by side collisions [2]. The intersection of urban traffic roads in China is mainly in the form of plane intersections. According to statistics, the death rate of 10,000 cars in China is 6.2, which is 4 to 8 times that of developed countries [3]. The casualty rate of side collision accidents accounts for a large part of the total accident casualties. Therefore, how to restore the accident more accurately and quickly after the occurrence of the side collision accident with high frequency and high casualty rate, thus providing a basis for the determination of the responsibility of the two parties, is a great challenge to the judicial authentication department.

In the current road traffic accident treatment, the reappearance and identification of the accident process is mainly to solve the collision process of cars and pedestrians when the accident occurs, in order to assist the traffic police to search and confirm the scene of the road traffic accident. At present, the software used for car crash analysis is PC-CRASH [4], accident analysis system of Chang'an University [5], etc. In the actual accident scene collection, due to the different measurement conditions, the surveyors and so on, the accident parameters collected are unavoidable, which will affect the accident analysis.

The sensitivity analysis of the velocity direction parameters before the collision and the position parameters of the collision center in the typical collision model is analyzed by Jianping Pei [6]. The mathematical expressions and the scope of application are given. It has important reference value for the specific application of typical collision models. Based on the collision test data of 16 cars to the cars, the influence of the tire model and the ground friction coefficient on the collision speed is calculated and analyzed by the car collision simulation software, and the quantitative boundary determines the degree of error that may be caused by Lang Wei [7]. Hongguo Xu [8] proposed a comprehensive evaluation method to calculate the velocity of collision. It can avoid the influence of the single method, the selection of parameters or the error of calculation, and can indirectly verify the authenticity of the remnants of some accident scene, and eliminate the evidence of some false images. Based on the analysis of car mechanics in motion, Yukai Lu [9] realizes the three-dimensional simulation of traffic accidents on the computer by using the principle of PC-CRASH trajectory optimization.

In this paper, the weight coefficients of car side impact accidents reconstructed by PC-CRASH are studied. Through the reconstruction of a real accident case, sorting of the input parameters design orthogonal experiment which affect the PC-CRASH accident reconstruction. Then an accident reconstruction method for adjusting the PC-CRASH input parameters according to the weight coefficient is proposed, and the effectiveness of the new method is verified by the two reconstruction of the accident case.

2. Influence Parameter Screening

Using PC-CRASH to restore traffic accidents, first of all, we need to collect and organize the PC-CRASH input parameters related to the accident. According to the difference of the method and accuracy of parameter acquisition, the relevant parameters are divided into three categories: accurate parameters, measurement parameters, and empirical parameters (**Table 1**). Accurate parameters are generally defined, standard, and accurate data. Measurement parameters refer to data obtained by accident gatherers at the scene of the accident or on the shape size of an accident car; the empirical parameters refer to the parameters which are difficult to obtain directly, generally through experience or empirical formulas.

In the above parameters, the estimation of the speed before collision is usually required by calculation formula. According to the law of conservation of energy and the calculation method of sequence number 3 in ≪ GB/T 33195-2016 road traffic accident speed identification ≫ [10], it can be found that the speed calculation formula for two cars when the car side collision is as follows:

$$v_1 = \left(\sqrt{2gs_1k_1\varphi_1}\cos\alpha + \frac{m_2}{m_1}\sqrt{2gs_2k_2\varphi_2}\sin\beta \right) * 3.6 \quad (1)$$

$$v_2 = \left(\frac{m_1}{m_2}\sqrt{2gs_1k_1\varphi_1}\sin\alpha + \sqrt{2gs_2k_2\varphi_2}\cos\beta \right) * 3.6 \quad (2)$$

In the formula:

v_1 v_2—The speed of two collision cars at the moment of a traffic accident (km/h)

g—Gravitational acceleration, take 9.8 m/s^2

φ_1 φ_2—Sliding adhesion coefficient of two collision cars

k k_2—Correction value of the adhesion coefficient of two collision cars

s_1 s_2—Slip distance after collision of two collision cars (m)

α β—Slip deflection angle of two collision cars (˚)

m_1 m_2—The quality of two collision cars (kg)

3.6—Coefficient of unit conversion

Since the accurate weighing m_1 m_2 can be carried out after the accident, the fixed value of the gravity acceleration g and the correction value of the adhesion coefficient k_1 k_2 are taken, so the above parameters are not taken into consideration when analyzing the influence of the parameters on the side collision accident reconstruction of the PC-CRASH. Because the final position of the two cars is fixed after the collision, the slip distance and slip angle of the two cars depend on the position of the collision point and the selection of the two cars angle when the collision is collided, so it is not considered.

Based on the above analysis, the following 11 parameters that have great impact on accident reconstruction are finally determined.: the position of the collision point, the angle of the two cars in the collision, the speed of the two cars in the collision, the friction coefficient of the tire and the ground, the height of the center of gravity of the two cars, the braking force of the two cars and the angle of the steering wheel of the two cars.

Table 1. PC-CRASH input parameters.

Classification	Parameter type	Software input parameters
Accurate parameters	car size parameters	The length, width, height, front suspension, wheelbase and wheelbase of a car.
	Tire parameters	Tire model
	Safety device	ABS configuration
	Engine parameters	Engine displacement, power
Measurement parameters	car shape parameters	*a b c d e f g* 1 2 3 4 5 6 7 8 (Specific meaning refer to PC-CRASH software)
	Quality parameters	Total quality of accident participants in collision
	Position parameter	The relative position and location of the collision point between the participants in the collision.
	Displacement parameters	The distance from the collision point to the final position.
Empirical parameters	Velocity parameter	The speed of each participant in a collision
	Friction coefficient parameters of pavement	The friction coefficient of the tire and the ground
	Center of gravity parameter	The center of gravity of each participant
	Operating parameters	The brake response time, braking force, steering wheel direction and size of each participant.

3. Accident Case Reconstruction

At 13:00 on January 19, 2016, the driver of the A car was driving from east to west and went to the intersection of the incident and collided with the B car driving from south to north. The accident resulted in damage to the right side of the front of the A car and the body of the B car, and two passengers were injured.

By combining the field trace, the law of conservation of energy, the traditional experience formula, PC-CRASH simulation and so on, after the accident reconstruction is carried out, the specific value of the parameters which have great influence on the reconstruction of the accident is found out in **Table 2**.

The final position map of the two cars and the final position of the actual two cars simulated by PC-CRASH are shown in **Figure 1**.

4. Parameter Weight Analysis

The weighting sorting of the 11 parameters that have a great influence on the reconstruction of the side collision accidents of the car is required for experimental analysis. However, due to the many factors affecting the test, if each level of each factor is matched with each other for a comprehensive test, the number of trials required will be very large. Therefore, this paper uses the orthogonal test [11] which can greatly reduce the number of trials and achieve better statistical results.

There are 11 factors to be considered in this test design, which are represented by A~K. According to the specific values of each parameter obtained by the

Table 2. PC-CRASH Parameter of accident reconstruction.

Collision point coordinates	Two cars' collision angle (˚)	A car's speed (km/h)	B car's speed (km/h)	Tire and ground friction coefficient	A car's center of gravity (m)
(1938.02, 488.77)	90	60	45	0.75	0.5
B car's center of gravity (m)	A car's deceleration (m/s^2)	B car's deceleration (m/s^2)	A car's steering wheel corner (˚)	B car's steering wheel corner (˚)	
0.5	4.0	5.4	−150	100	

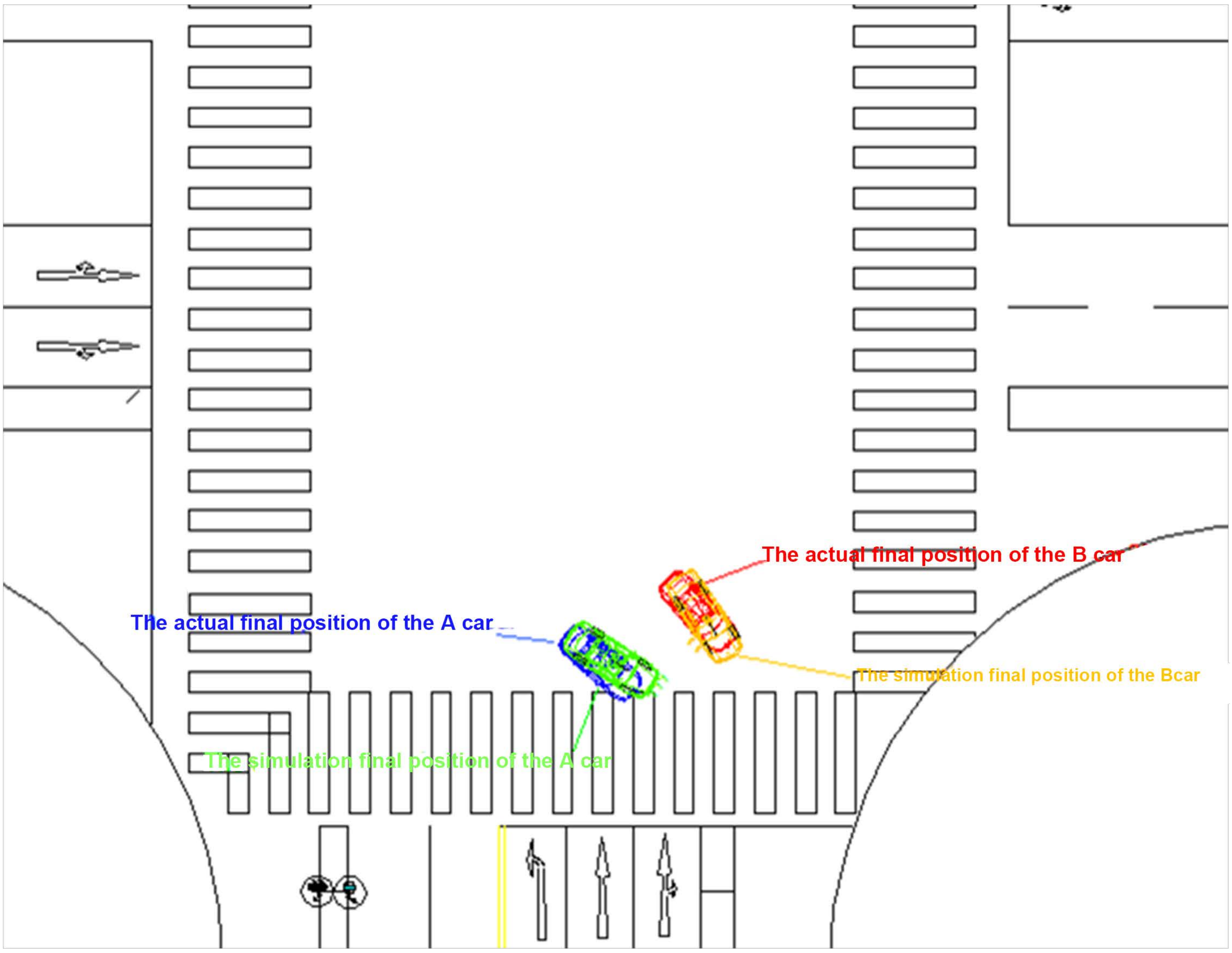

Figure 1. The final position map of the two cars.

above accident reconstruction, an orthogonal test of 11 factors and 3 levels is arranged, in which the values of each level are within a reasonable range of variation, and the factor level table is shown in Table 3.

According to the factor level table, the distance$(X_1,X_2)/(m)$ between the center of gravity of the A and B two cars after the change of parameters and the center of gravity after the actual A and B two cars stopped as the test index. The designed test plan and simulation results are shown in Table 4.

The direct analysis method of orthogonal test design is to calculate the influence of all factors and levels on the result of the test results through the analysis

Table 3. Factor level table.

Level	Collision point coordinates	Two cars' collision angle/(˚)	A car's speed/(km/h)	B car's speed/(km/h)	Tire and ground friction coefficient	A car's center height/m
Symbol	A	B	C	D	E	F
1	(1938.02, 488.47)	80	55	40	0.70	0.45
2	(1938.02, 488.77)	90	60	45	0.75	0.50
3	(1938.32, 488.77)	100	65	50	0.80	0.55
Level	B car's center height/(m)	A car's deceleration/(m/s^2)	B car's deceleration/(m/s^2)	A car' steering wheel corner/(˚)	B car's steering wheel corner/(˚)	
Symbol	G	H	I	J	K	
1	0.45	3.0	4.4	−140	90	
2	0.5	4.0	5.4	−150	100	
3	0.55	5.0	6.4	−160	110	

Table 4. Test scheme table and simulation result.

Test	A	B	C	D	E	F	G	H	I	J	K	X1	X2
1	(1938.02, 488.47)	80	55	40	0.70	0.45	0.45	3.0	4.4	−140	90	7.3	16.8
2	(1938.02, 488.47)	80	55	40	0.75	0.50	0.5	4.0	5.4	−150	100	7.6	2.8
3	(1938.02, 488.47)	80	55	40	0.80	0.55	0.55	5.0	6.4	−160	110	6.9	4.7
4	(1938.02, 488.47)	90	60	45	0.70	0.45	0.45	4.0	5.4	−150	110	9.0	0.7
5	(1938.02, 488.47)	90	60	45	0.75	0.50	0.50	5.0	6.4	−160	90	8.4	2.1
6	(1938.02, 488.47)	90	60	45	0.80	0.55	0.55	3.0	4.4	−140	100	11.1	2.8
7	(1938.02, 488.47)	100	65	50	0.70	0.45	0.45	5.0	6.4	−160	100	10	1.7
8	(1938.02, 488.47)	100	65	50	0.75	0.50	0.50	3.0	4.4	−140	110	12.9	4.6
9	(1938.02, 488.47)	100	65	50	0.80	0.55	0.55	4.0	5.4	−150	90	12.2	4.2
10	(1938.02, 488.77)	80	60	50	0.70	0.50	0.55	3.0	5.4	−160	90	10.5	5.3
11	(1938.02, 488.77)	80	60	50	0.75	0.55	0.45	4.0	6.4	−140	100	9.3	2.1
12	(1938.02, 488.77)	80	60	50	0.80	0.45	0.50	5.0	4.4	−150	110	10.6	5.8
13	(1938.02, 488.77)	90	65	40	0.70	0.50	0.55	4.0	6.4	−140	110	5.9	3.1
14	(1938.02, 488.77)	90	65	40	0.75	0.55	0.45	5.0	4.4	−150	90	7.1	2.9
15	(1938.02, 488.77)	90	65	40	0.80	0.45	0.50	3.0	5.4	−160	100	6.0	2.5
16	(1938.02, 488.77)	100	55	45	0.70	0.50	0.55	5.0	4.4	−150	100	10	2.8
17	(1938.02, 488.77)	100	55	45	0.75	0.55	0.45	3.0	5.4	−160	110	8.1	3.9
18	(1938.02, 488.77)	100	55	45	0.80	0.45	0.50	4.0	6.4	−140	90	7.4	4.9
19	(1938.32, 488.77)	80	65	45	0.70	0.55	0.50	3.0	6.4	−150	90	9.4	1.3
20	(1938.32, 488.77)	80	65	45	0.75	0.45	0.55	4.0	4.4	−160	100	11.1	6.1
21	(1938.32, 488.77)	80	65	45	0.80	0.50	0.45	5.0	5.4	−140	110	7.7	1.7
22	(1938.32, 488.77)	90	55	50	0.70	0.55	0.50	4.0	4.4	−160	110	11.5	5.2
23	(1938.32, 488.77)	90	55	50	0.75	0.45	0.55	5.0	5.4	−140	90	12.4	5.7
24	(1938.32, 488.77)	90	55	50	0.80	0.50	0.45	3.0	6.4	−150	100	10.4	4.7
25	(1938.32, 488.77)	100	60	40	0.70	0.55	0.50	5.0	5.4	−140	100	6.6	2.7
26	(1938.32, 488.77)	100	60	40	0.75	0.45	0.55	3.0	6.4	−150	110	6.2	3.5
27	(1938.32, 488.77)	100	60	40	0.80	0.50	0.45	4.0	4.4	−160	90	7.5	1.8

of extreme difference and comprehensive comparison in order to determine the optimal test scheme, sometimes also called the extreme analysis method. The range is large shows that this factor has a great influence on the index and is an important factor; the range is small shows that this factor has little influence on the index, and is usually an unimportant factor, and the extreme calculation formula for each factor is the difference. The range formula for each factor is

$$R_j = \max_{1\le l\le r} \overline{K}_{lj} - \min_{1\le l\le r} \overline{K}_{lj}, j = 1,2,\cdots,p \tag{3}$$

In the formula:

$$\overline{K}_{lj} = K_{lj} / m\left(l = 1,2,\cdots,r; j = 1,2,\cdots,p\right)$$

$K_{lj}\left(l = 1,2,\cdots,r; j = 1,2,\cdots,p\right)$ represent the sum of the m test results corresponding to the horizontal l in the column j of the orthogonal table, and m is the number of times that each level appears in the test plan.

Table 4 is used to analyze the range analysis tables of two indicators, as shown in Table 5 and Table 6.

Through the above range analysis table, comparing the range values of various factors, it can be concluded that when PC-CRASH is used to reconstruct the side impact accident:

1) Parameter weight ranking of A car accident reconstruction is：Speed of side damaged collision car > Deceleration of side damaged collision cars > Collision point coordinates > Center height of side damaged collision cars > Tire and ground friction coefficient = Steering wheel corner of side damaged collision cars > Speed of frontal damaged collision car = Steering wheel corner of frontal damaged collision cars > Two cars' collision angle = Center height of frontal damaged collision cars = Deceleration of frontal damaged collision cars.

2) Parameter weight ranking of B car accident reconstruction is: Speed of frontal damaged collision car > Deceleration of side damaged collision cars > Center height of frontal damaged collision cars > Two cars' collision angle = Steering wheel corner of side damaged collision cars > Deceleration of frontal damaged collision cars = Steering wheel corner of frontal damaged collision cars>Speed of side damaged collision car > Collision point coordinates > Center height of side damaged collision cars = Tire and ground friction coefficient.

5. Method Verification

First, the classical car speed formula (1) (2) and the calculation of the accident parameters required by the car speed are shown in Table 7, and the speed of two cars collision is calculated.

The parameters in Table 7 are brought to type (1) (2), and obtain the speed of A car before collision is 60.5 m/s, the speed of B car before collision is 47 km/h.

By selecting the speed in the speed range of the two cars and the weight sorting of the reconstruction parameters of the car side impact PC-CRASH accident reconstruction, the accident case was reconstructed second times and the second reconstruction results were shown in Figure 2.

Table 5. The extreme analysis table of index X_1.

Test	A	B	C	D	E	F	G	H	I	J	K
$\overline{K}_{1j}$	9.5	8.9	9.1	6.8	8.9	8.9	8.5	9.1	9.9	8.9	9.1
$\overline{K}_{2j}$	8.3	9.1	8.8	9.1	9.2	8.9	8.9	9.1	8.9	9.2	9.1
$\overline{K}_{3j}$	9.2	8.9	9.1	11.1	8.9	9.1	9.6	8.8	8.2	8.9	8.8
R_j	1.2	0.2	0.3	4.3	0.4	0.2	1.1	0.2	1.7	0.3	0.4

Table 6. The extreme analysis table of index X_2.

Test	A	B	C	D	E	F	G	H	I	J	K
$\overline{K}_{1j}$	4.5	5.2	5.7	4.5	4.4	5.3	4.0	5.0	5.4	4.9	5
$\overline{K}_{2j}$	3.7	3.3	2.9	2.9	3.7	3.2	3.5	3.4	3.3	3.2	3.1
$\overline{K}_{3j}$	3.6	3.3	3.1	4.4	3.7	3.3	4.2	3.3	3.1	3.7	3.7
R_j	0.9	1.9	2.7	1.6	0.7	2.1	0.7	1.7	2.3	1.7	1.9

Table 7. Range of parameter value of car speed calculation.

Speed calculation parameters of two cars	Range of value	Speed calculation parameters of two cars	Range of value
φ_1	0.75 ± 0.05	φ_2	0.75 ± 0.05
s_1/m	17.5	s_2/m	9.5
m_1	1670	m_2	1540
α/(˚)	40	β/(˚)	41

Taking the error value of the position of the car's gravity center after the two reconstruction and the center of gravity of the actual car after stopping, the two accident reconstruction results were evaluated. The results of the two accident reconstruction results in **Table 8**.

As can be seen from **Table 8**, the second reconstruction has a final stop position of the two cars closer to the true stop position than the first reconstruction. Therefore, it can be concluded that in the car side collision accident reconstruction, according to the PC-CRASH parameter weight of the car side collision, the weight of the input parameters is adjusted from large to small, and the accident can be rebuilt more accurately.

(1945.42, 472.94)

(1950.31, 475.40)

(1945.42, 472.94)

(1950.31, 475.40)

(1945.42, 472.94)

(1950.31, 475.40)

(1945.42, 472.94)

(1950.31, 475.40)

(1945.42, 472.94)

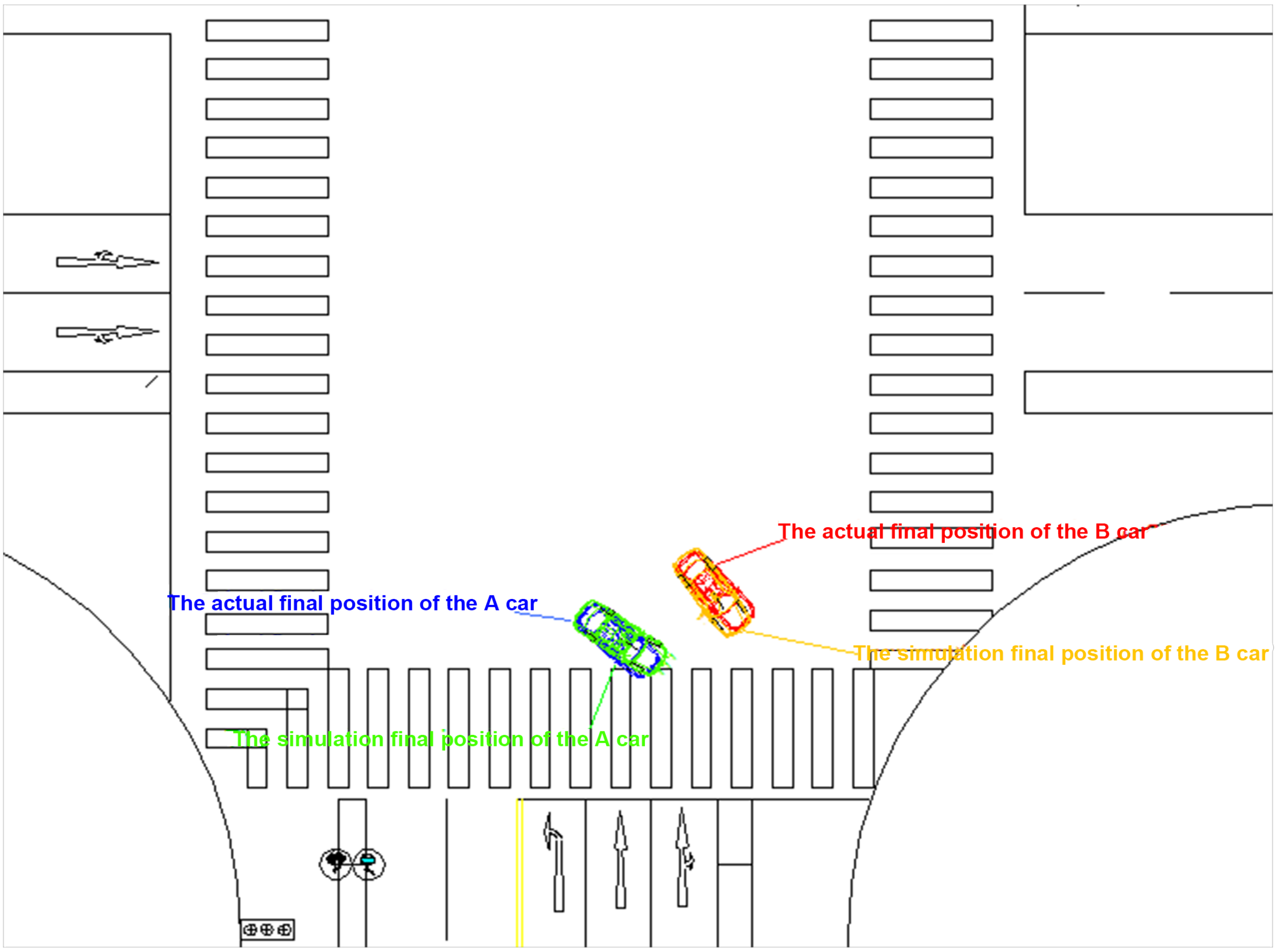

Figure 2. Second reconstruction of the final position of the car.

Table 8. Contrast table of reconstruction results.

	Center of gravity position error of A car/m	Center of gravity position error of B car/m
First reconstruction	0.22	0.27
Second reconstruction	0.15	0.19

(1950.31, 475.40)
(1945.42, 472.94)
(1950.31, 475.40)
(1945.42, 472.94)
(1950.31, 475.40)
(1945.42, 472.94)
(1950.31, 475.40)
(1945.42, 472.94)
(1950.31, 475.40)

6. Conclusion

1) Through the orthogonal experiment and the range analysis of the selected

11 parameters, it can be seen that the biggest influence factor on the car side collision accident reconstruction is the speed of the two cars before the collision.

2) According to the obtained PC-CRASH accident reconstruction parameter weight and the targeted adjustment parameters can improve the accuracy of accident reconstruction.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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