Design Engineering

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116

Traffic Simulation Method for Dynamic Road Network Model Construction Based on Oblique Aerial Photogrammetry Technology

Haixiao Wang[1,*], Chutong Wang[2], Jiangwei Shen[1]

[1]School of Energy and Transportation Engineering, Inner Mongolia Agricultural University, Hohhot 010018, China

[2]The Nottingham University Business School, Ningbo, 315100, China

*Corresponding Author: Haixiao Wang

Abstract:

In order to improving the accuracy and authenticity in traffic simulation, we propose the Oblique aerial photogrammetry technology to the simulation process to build dynamic road network model in three stages. First, we extract the 3D linear data from real measurements and complete the data settlement by oblique aerial photogrammetry technology and photogrammetry software. Then, we transform aerial data into a simulation file (INP) through a self-complied program and matched with VISSIM. Finally, we choose a slope section and intersection in Nanning City as experimental scheme for road network modelling simulation. Through comparing and analysing the differences in simulation results of road network models based on new method (hereinafter referred to as OAP) and traditional method from the aspects of road alignment, vehicle type, and traffic loads, we draw a conclusion that using the OAP method could be more intelligent and accurate in the road alignment, especially on slope sections, meanwhile the simulation evaluation indicates the OAP method also has better precision of practical traffic states and higher accuracy of simulation parameters.

Keywords: *Oblique aerial photogrammetry, Traffic simulation, Bentley open roads designer, PTV-VISSIM.*

I. INTRODUCTION

PTV-VISSIM is a primary traffic simulation software, offering complete integration, user-friendly and vivid interface, support of multi-user parallel computing, perfect demonstration function, fast version update, good generalization performance, and strong secondary development capability [1]. In traditional method, the road network data acceptable to VISSIM mainly comes from the following directions: the road network abstract model from Synchro7

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116

type and Visum (ANM), another method is to use BIM engineering software to export modelling. Frequently the modelling method that we use most is a road network editor in VISSIM, users need to import vector diagram (CAD graphs) or satellite pictures as base pictures onto which the road network is manually drawn [2]. Thus, the modelling accuracy depends on the quality of the imported satellite images. If the resolution ratio of satellite images is fuzzy, then there will be an increased difference between the road network model and practical conditions [3]. Due to technological limits, we adopt a simplified process to generalize road alignment and gradient in VISSIM, so the resulting road section lacks complete horizontal alignment and longitudinal section alignment [4-6]. To show the alignment of longitudinal section of the road, the elevation values at different points must be inputted one at a time. However, the inclusion of a large amount is typically preferred to ensure accuracy of static parameters, and the manual input of a number of values becomes an arduous task [7].

Oblique aerial photogrammetry (OAP) is successfully applied in many fields such as intelligent transportation, road and bridge construction design, and urban planning [8]. For example, Zhao et al. [9] applied Convolutional Neural Network (CNN) and Speeded up Robust Features (SURF) to estimate traffic flow parameters from UAV videos with no ego-motion. Ke et al. [10] proposed a new and complete analysis framework for traffic flow parameter estimation from UAV video. Wang et al. [11] estimated 3D trajectory modelling for UAV, their method made use of UAV in extraction of traffic parameters. OAP can be used for height, Angle, area and volume measurements, and high precision model production can be achieved through ground street view measurements and retakes, to overcome the impact of altitude masks [12-13]. Based on the above application, we establish the road network model which is redrawn a road network using aerial photogrammetry technology (UAV videos).

II. NEW METHOD (OAP METHOD)

2.1 Aim of OAP Method

In traditional method, the influence of static data from the aspect of road alignment is still exit. The horizontal and longitudinal alignments of the road are the most important static data in traffic simulation, and have a great influence on traffic-flow indexes [14]. As part of the road alignment process, the average speed of traffic on the road has a linear relationship with curvature, which can be expressed with the following formula [15]:

$$V_t = 70.04 - 1.2D \tag{1}$$

The influence of curvature and gradient on speed can be expressed with the following formula:

$$\Delta\bar{V} = 1.96D + 2.2G \tag{2}$$

Wherein, V_t is the average travel speed; $\Delta\bar{V}$ is the minimum of average speed; D is the curvature number; G is the average longitudinal gradient of slope.

Setting smooth transition of changing-slope-point is the core of improving static data precision, which cannot be achieved by traditional method. OAP method could simulate the slow gradual change of linear shape at the changing-slope-point, replacing the abrupt change of

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116

velocity and acceleration at this point, so as to make the describing terrain of the static data more accurate and improve the accuracy of simulation.

2.2 Modelling Process of OAP Method

Fig 1 shows the modelling process of OAP method. OAP technology can obtain images to build 3D scenes in real coordinate system, and directly generate real scene topography (Live-action model) from Context Capture software [16]. Open Roads Designer (ORD) is used to extract the alignment data for a road from the live-action model, the design document unit of ORD is set to the metric system (m) to use the same unit system for both live-action model and VISSIM, plane geometry tools include straight line, circular curve, and transition curve in ORD. Using top view and plane geometry tools, straight, circular, and gentle line segments are drawn closely to the double yellow lines of the road [17,18]. The form line in the viewport is actually the true longitudinal section of the road, we use Building Block Approach (BBA) drawing a straight line and circular curve closely to the form line, giving a 3D curve close to the double yellow line of the road. Finally, the labelling tool is used to output equally spaced points on the 3D curve as TXT text in the form of X/Y/Z coordinates.

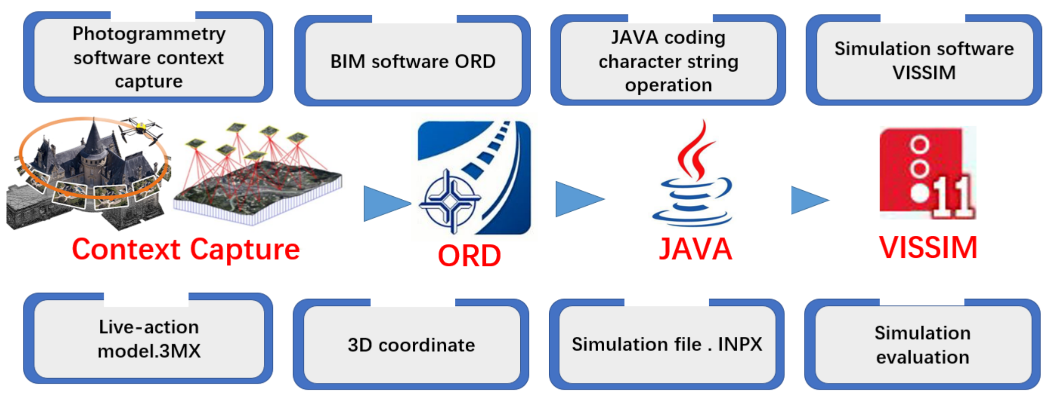


Fig 1: Modelling process of 3D road network based on live-action model

After extracting alignment data of road, we will embed the extracted 3D data to rebuild 3D road alignment into the corresponding position of the file. The x/y/z coordinates values of each line are read through character string splicing to gain the object code by using Java. After splicing of the coordinate data files, the data are written into the new file line-by-line, then the object file generated.

III. CASE DESCRIPTION

3.1 Experimental Section and Data Source

The study site is the intersection and slope section in Nanning city, during the experiment, using video survey method (including medium and low vantage point positioning camera and unmanned aerial photography), we can extract current road data from Bentley ORD, as shown in TABLE I. Meanwhile, choosing coil acquisition method and manual recording to get the measured traffic data.

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116

TABLE I. Data sections of road network in Nanning city

Points ID	X	Y	Z	Gradient	Direction
100000001	19084226.5227	9226136.2139	2075.4842	0	all
100000002	19084225.0081	9226146.0985	2075.6842	0	all
100000003	19084223.4936	9226155.9832	2075.8842	0	all
…	…	…	…		…
100996726	14854212.8917	7226274.0503	2176.2842	0.6739	all
…	…	…	…		…
102367984	1032745.7365	8104126.6148	2495.5468	1.1209	all
…	…	…	…		…

3.2 Modelling Case

The test section is selected in the section of a ramp and the intersection where the ramp connects so as to reflect the simulation effect of slope changing region. An intersection of Nanning City was chosen as the object of the experiment, as shown in Fig 2. The first part is the simulation of average velocity and acceleration at a slope segment and the second part is the simulation of intersection delay.

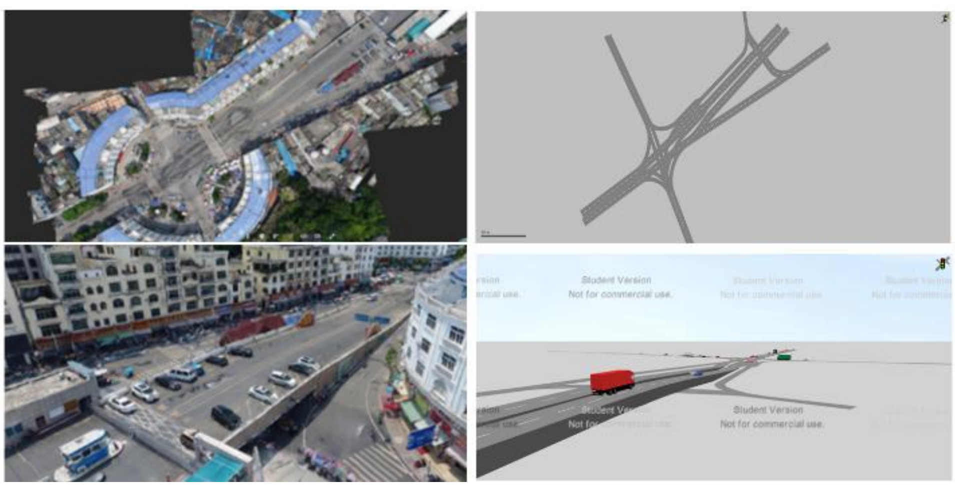


Fig 2: The road network models of intersection and slope in Nanning

We use each two methods to complete the road network modelling, precision of 2M, experimental environment was VISSIM 9.09, each simulation lasted 3600s, and simulation precision was 10 time length/simulation second.

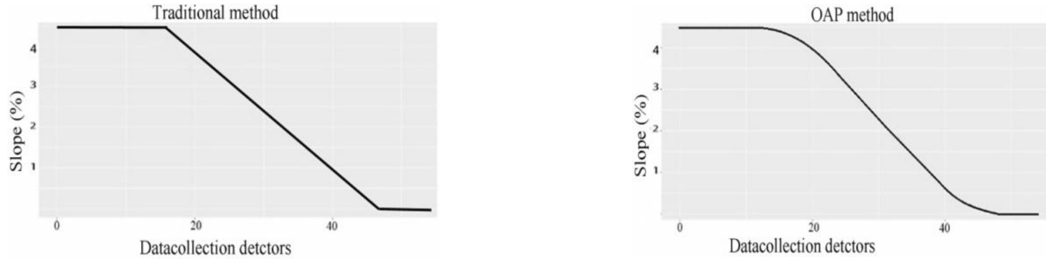
IV. CONTRASTIVE ANALYSIS IN THE SLOPE SECTION

4.1 Contrastive Analysis of Longitudinal Slope Simulation

The intersection has four entrances, the eastern entrance is a downhill with complex longitudinal section alignment (longitudinal slope is about 4.5%). The alignment of other entrance is simple, the slope is fixed at 0.2%. So the eastern entrance was chosen as

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116

experimental object, data collection detectors were arranged at intervals of 2m from the slow gradient change at the eastern entrance approach to the stop line, and numbered in ascending order. In this experiment, the horizontal alignment of the eastern entrance of intersection is a straight line, so the biggest difference is apparent at the slope change position of the longitudinal section.



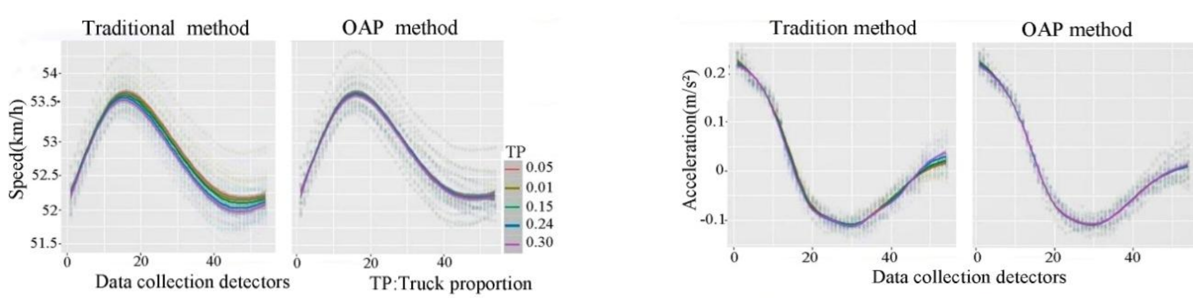
(a) Longitudinal slope value in traditional method (b) Longitudinal slope value in OAP method

Fig 3: Comparison of longitudinal slope between two methods

The longitudinal alignment of road models established by two methods is shown in Fig 3. In the traditional method, the longitudinal alignment is abstractly generalized by straight lines, the longitudinal slope changes suddenly, and is composed of broken lines, so it is significantly different from practical conditions. The model based on OAP is established according to the 3D coordinates of the road section extracted from the terrain in the live-action model, includes detailed conditions of section alignment, changes gradually, and is close to the pavement to better reflect actual road alignment.

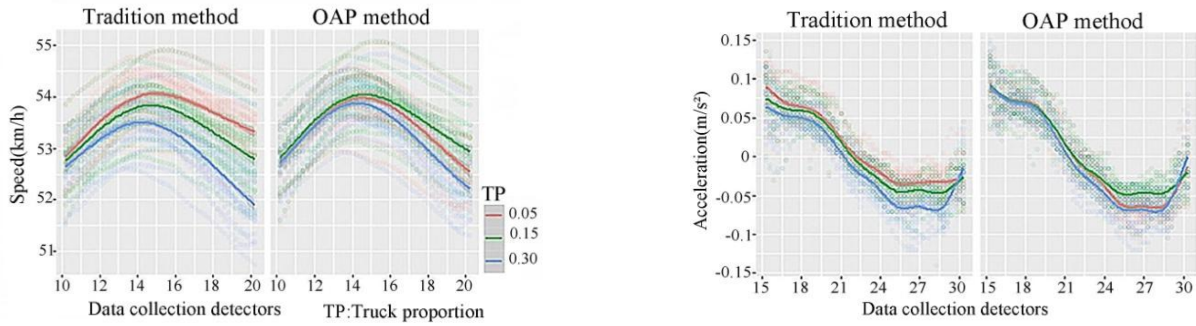
4.2 Simulation of Two Methods under Different Truck Proportion

Compared with cars, trucks have high sensitivity to the longitudinal gradient, especially when the gradient is greater [19]. Traffic composition was used as an independent variable of the experiment in this part, the traffic-flow was 500/h, random seed number was 30, and random seed increment was 2. Simulation was carried out 20 times for five conditions in which the proportion of trucks was 5%, 10%, 15%, 24%, or 30%. Speed and acceleration data of 200 groups (10800 sample points) were collected. The nonlinear fitting with the confidence range of 95% was conducted for the data.



(a) Speed fitted curve in eastern entrance (b) Acceleration fitted curve in eastern entrance

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116



(c) Speed fitted curve in changing-slope-point (d) Acceleration fitted curve around changing-slope-point

Fig 4: The speed and acceleration under different truck proportion in the two methods

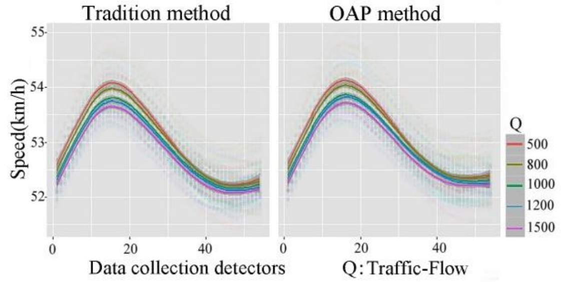
As shown in Fig 4 (a, b), the regression curve indicates that speed reaches the peak and valley value at the changing-slope-point or around, the minimum value of acceleration is in the braking process of downhill, before the slope changes. The speed distribution is dispersed in the traditional method on the whole slope, while more consistent in the OAP method. The acceleration distribution curve of the whole slope has a similar pattern in two methods. To make parameter variations at the changing-slope-point more detailed and clear, acceleration parameters were compared under three typical states (5%, 15%, and 30% trucks), the data of variable slope are analyzed accurately, as shown in Fig 4 (c, d). In the changing-slope-point (detectors 10-20), vehicle speed of different proportion of trucks present more differences in traditional method than in OAP.

The reason for this difference is that in the traditional model, longitudinal section suddenly changes in the transition region to 4.5% uphill from 0% horizontal, the speed difference immediately appears due to the slope change. In OAP method, the gradient gradually changes, so no obvious difference in speed, acceleration of traffic-flow for different proportion of trucks. For actual driving conditions, the speed will not change suddenly. Therefore, in the OAP, the changes in speed, acceleration were better conform to the driving state of an actual slope, thus, the simulation effect is more realistic.

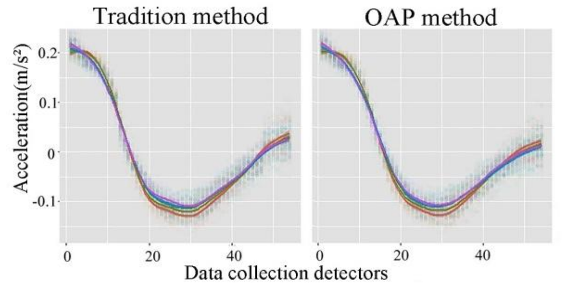
4.3 Simulation of Two Methods under Different Traffic Loads

The traffic-flow was used as an independent variable to further study the influence of traffic-flow and modelling method on simulation results. In this experimental process, the random seed number was 30, the random seed increment was 2, and the proportion of trucks was 20%. Simulation was carried out 20 times under traffic-flow volumes of 500 pcu/h, 800 pcu/h, 1000 pcu/h, 1200 pcu/h, 1500 pcu/h with a confidence range of 95%. Vehicle speed, acceleration data of 200 groups (10800 sample points) were gained.

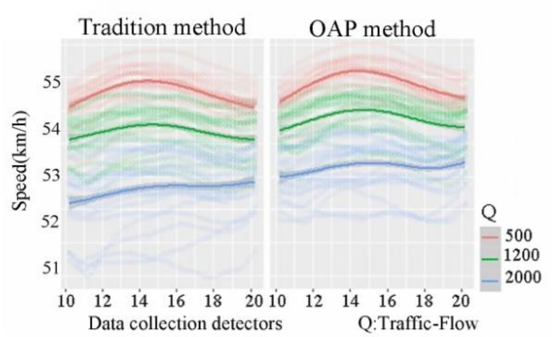
ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116



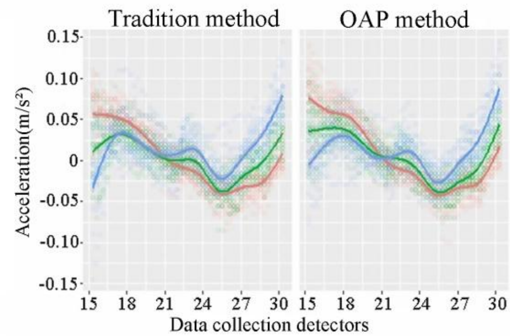
(a) Speed fitted curve in eastern entrance



(b) Acceleration fitted curve in eastern entrance



(c) Speed fitted curve in changing-slope-point



(d) Acceleration fitted curve around changing-slope-point

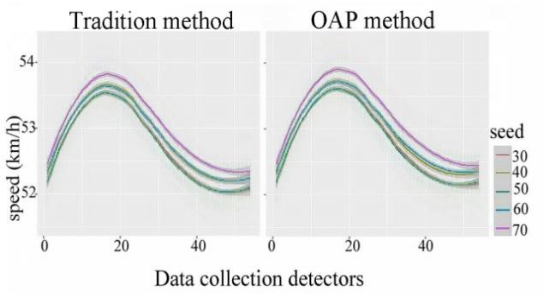
Fig 5: The speed and acceleration under different traffic-flow in the two methods

As shown in Fig 5, the regression curve indicates that the traffic-flow is larger, the speed is lower. The speed in the OAP method is little higher and the acceleration is more smooth than in traditional method. At the changing-slope-point position, while vehicles in the OAP method showed differences of speed and acceleration before the vehicles enter the changing-slope-point. In the changing-slope-point, for each position, the speed of the OAP method was higher than traditional method, and the change of acceleration curve slope is gentle, consistent with driving behavior at this point. The reason is horizontal section where gradually changes, the acceleration and deceleration operation advances, so that under different traffic-flow shows the gap before entering the horizontal slope. The traditional method cannot accurately describe this altered change point.

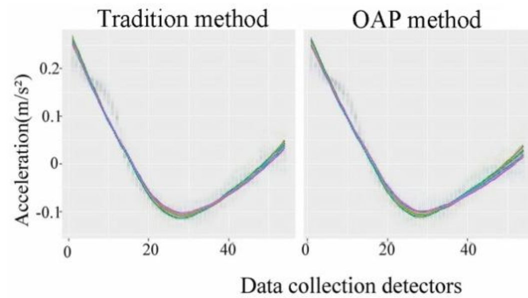
4.4 Simulation of Two Methods under Different Random Seed Number

The change of random seed number will influence the arrival law of traffic-flow [20]. In the experimental process, the random seed number was used as an independent variable, the traffic-flow was 1000 pcu/h, and the proportion of trucks was 20%. The simulation was performed 10 times for each of five conditions (random seed number of 30, 40, 50, 60, and 70). The random seed increment was 1, and 100 groups of data (5400 sample points) were obtained. Nonlinear fitting of the data was performed with a confidence range of 95%.

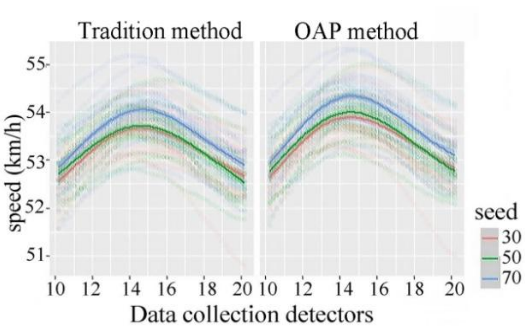
ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116



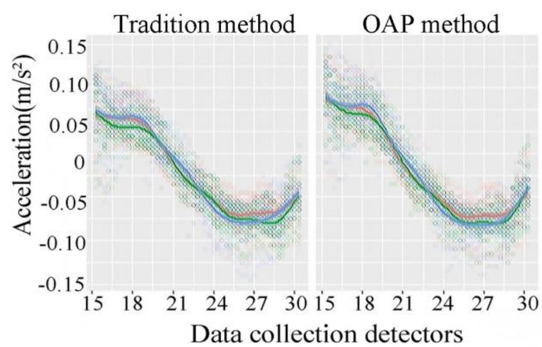
(a) Speed fitted curve in eastern entrance



(b) Acceleration fitted curve in eastern entrance



(c) Speed fitted curve in changing-slope-point



(d) Acceleration fitted curve around changing-slope-point

Fig 6: The speed and acceleration under different random seed number in the two methods

As shown in Fig 6: the simulation results were in general consistent for the two methods. After the positions around the slope change were subdivided, the conclusion was consistent with the overall section trend. For different seed numbers, the speed and acceleration parameters changed little, indicating only a small influence of random seed number on simulation parameters under the two methods, which conforms to the rules of the VISSIM simulation parameters.

V. CONTRASTIVE ANALYSIS OF ENTRANCE DELAY

Because the gradient of other entrance section in this case is 0.2%, in the traditional model, this small gradient could not be measured, so a default gradient of 0% was used. Statistically, the difference of entrance delay simulation mainly distributed in slope entrance, therefore, we still select eastern entrance for further comparison of two methods using measured values by manual investigation.

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116

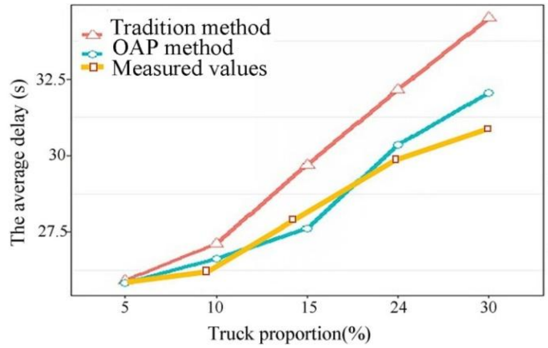


Fig 7: The average delay in different truck proportion

As shown in Fig 7, there are differences in the average delay of the entrance in the two methods. Since the proportion of trucks changes, there is a large queue length for the single lane with small traffic capacity. When the proportion of trucks is higher, the space occupied is larger, and more vehicles stop farther back from the stop line. When there is a red light, the acceleration and deceleration change will directly influence delay and parking time. When the proportion of trucks increases, vehicle position, acceleration, and deceleration are influenced, the change caused by this influence is gradual and advanced in the OAP method, which is consistent with the measured values and actual driving process. Comparatively, in the traditional method the change caused by this influence is sharply and accumulated, so there are relative obvious defects.

5.1 Simulation of Two Methods under Different Traffic Loads

Intersection delay has a direct relationship with the traffic loads of the intersection [21]. In this part, we set up five traffic-flow schemes, and conduct for each scheme 20 simulations, the average delay value was taken as the result.

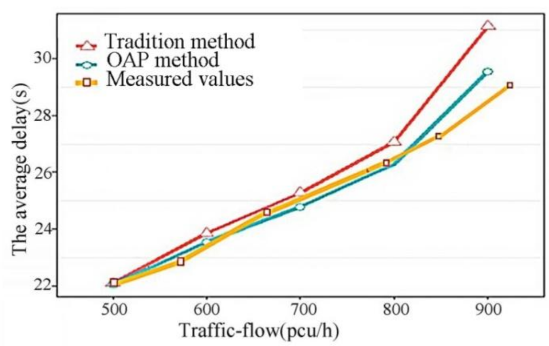


Fig 8: The average delay in different traffic loads

As shown in Fig 8, the result indicates that the larger the traffic-flow, the more obvious the differences. The root cause of the difference still lies in the gradient difference. On the entrance with the low traffic-flow, the traditional method can simulate approximate operation conditions of traffic-flow as well as OAP method, and the gradient deviation has little influence on the delay value. When the traffic-flow is a little heavier, the gradient deviation will lead to a significant increase in queue delays but not rapid growth, the traditional method will lead to small amplitude skewing in delay curve and The OAP will not.

5.2 Simulation of Two Methods under Different Random Seed Number

The following, we set the random seed number 30, 40, 50, 60, or 70 in the experimental process, the random seed increment was 1, and 10 simulations were conducted for each random seed number.

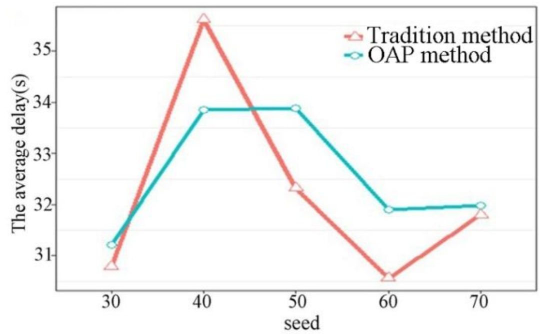


Fig 9: The average delay in different random seed number

As shown in Fig 9, the experimental result indicates that for different random seed number, there is a significant difference in the eastern entrance. In VISSIM evaluation process, the default seed number is 42 as to obtain a higher delay value as the upper limit of delay parameter, and close to 40 the maximum delay value is usually obtained. Both methods conform to this rule, but the influence of seed number on OAP method is weak, and abnormal queuing phenomenon will not occur due to the change of vehicle arrival rate, which is consistent with the actual driving habits and driving behaviors of drivers.

VI. CONCLUSION

In this study, we were exploring the OAP method to establish road network simulation based on oblique aerial photogrammetry technology and related software. Through comparing and studying the differences in simulation results of the experimental scheme, OAP method is closer to actual traffic-flow conditions than the road network model established by the traditional method. The OAP method has wide applicability and generalization performance, and the conversion between extracted 3D data and generated road network data can be completed in batch conveniently.

This is the first proposed method to establish a traffic simulation road network based on oblique aerial photogrammetry technology. At the same time, it could also shoulder the modelling task of the whole city and build a 3D urban road network system for the city. Meanwhile, when entering the simulation stage of complex traffic conditions and driving behaviors, it cannot reflect the advantages of more intelligent than traditional methods. Further research should seek to increase the goodness of fit of simulation data, improve simulation software precision, various driving behavior models should be built into the simulation software, and automatically establish a simulation road network.

ACKNOWLEDGEMENT

The authors acknowledge the Natural Science Foundation of Inner Mongolia (Grant: 2019MS05005), and the Inner Mongolia University Scientific Research Project (Grant: NJZY17065).

REFERENCES

[1] Hale D. K., Antoniou C., Brackstone M., et al., (2012) Optimization-based assisted calibration of traffic simulation models, in Transportation Research Part C 55: 100-115.

[2] Yu B., Liu C., Wang Z., (2012) Development of a computer system for simulation of traffic models, in Journal of Computing in Civil Engineering 28(2): 223-231.

[3] Hidas P., (2002) Modelling lane changing and merging in microscopic traffic simulation, in Transportation Research Part C (Emerging Technologies) 10 (5-6): 351-371.

[4] Wang C., Xu C.C., Xia J.X., et al., (2018) A combined use of microscopic traffic simulation and extreme value methods for traffic safety evaluation, in Transportation Research Part C Emerging Technologies, 90: 281-291.

[5] Biagio C., Carlos L. A., (2014) A sensitivity-analysis-based approach for the calibration of traffic simulation models, in IEEE Transactions on Intelligent Transportation Systems 15(3): 1298-1309.

[6] Gwon G.P., Hur W.S., Kim S.W., et al., (2014) Generation of a precise and efficient lane-level road map for intelligent vehicle systems, IEEE Transactions on Vehicular Technology 66(6): 4517-4533.

[7] Betaille D., Moreo R.T., (2010) Creating enhanced maps for lane-level vehicle navigation, in IEEE Transactions on Intelligent Transportation Systems 11(4): 786-798.

[8] Li Y. C., Liu Y. H., Su Y. Q., et al., (2016) Three-dimensional traffic scenes simulation from road image sequences, in IEEE Transactions on Intelligent Transportation Systems 17(4): 1121-1134.

[9] Zhao X., Dawson D., Sarasua W. A., (2017) Automated traffic surveillance system with aerial camera arrays imagery: Macroscopic Data Collection with Vehicle Tracking, in Journal of Computing in Civil Engineering 31(3): 04016072.

[10] Ke R. M., Li Z. B., Tang J. J., et al., (2018) Real-time traffic flow parameter estimation from UAV video based on ensemble classifier and optical flow, in IEEE Transactions on Intelligent Transportation Systems 99: 1-11.

[11] Wang B. Q., et al., (2019) 3-D Trajectory modelling for unmanned aerial vehicles. AIAA Scitech 2019 Forum

[12] Zong F., Tian Y. D., He Y. N., Tang J. J., et al., (2019) Trip destination prediction based on multi-day GPS data, in Physica A 515(1): 258-269.

[13] Haklay M., Weber P., (2008) Openstreetmap: user-generated street maps, in IEEE Pervasive Computing 7(4): 12-18.

[14] Gikas V., Stratakos J., (2012) A novel geodetic engineering method for accurate and automated road/railway centerline geometry extraction based on the bearing diagramand fractal behavior, in IEEE Transactions on Intelligent Transportation Systems 13(1): 115-126.

[15] Ran X, Li L, Zhao X, Song J, et al., (2016) Real-time recognition algorithm of longitudinal road slope based on vehicle dynamics and acceleration sensor information, in Journal of Mechanical Engineering 52(18): 98-104.

ISSN: 0011-9342
Issue: 10 | Pages: 105 - 116

[16] Gwon G. P., Hur W. S., Kim S. W., et al., (2017) Generation of a precise and efficient lane-level road map for intelligent vehicle systems, in IEEE Transactions on Vehicular Technology 66(6): 4517-4533.

[17] Shang L., Lu H. P., (2006) Urban microscopic traffic simulation system and its application, in Journal of System Simulation 18(1): 221-224.

[18] Yang B., Fang L., Li J., (2013) Semi-automated extraction and delineation of 3d roads of street scene from mobile laser scanning point clouds, in Isprs Journal of Photogrammetry & Remote Sensing 79(5): 80-93.

[19] Wang H. X., Liu F., Tang J. J., (2018) Exploring intra-urban travel mobility using large-scale Taxi global positioning system trajectories, in International Journal of Vehicle Structures & System 10(2): 150-159.

[20] Zyryanov V., Kocherga V., Topilin I., (2017) Investigation of dependencies between parameters of two-component models of the kinetic theory of traffic flow and traffic characteristics, in Transportation Research Procedia 20: 746-750.

[21] Tang J. J., Liang J., Zhang S., et al., (2018) Inferring driving trajectories based on probabilistic model from large scale taxi GPS data, in Physica A 506(1): 566-577.