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Research article

A data-based framework for automatic road network generation of multi-modal transport micro-simulation

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Abstract: In microscopic traffic simulation, the fidelity of the road network model has a significant impact on the difference between the simulation and the actual urban traffic state. Accurately matching data on the simulated road network and the surroundings has become a central concern in traffic simulation research. This study provides a multi-source data-based framework for automatic road network generation (ARNG) to address the issue of manual procedures in the creation of the simulated road network and surroundings. First, the proposed method of fusion and matching of diverse road network data is used to acquire the basic road network information, and the combining of the features of different road network data can enhance the authenticity of the basic road network. Second, a multi-modal simulation road network is developed based on multi-modal traffic operation data to serve as the simulation operation's foundational environment. To address the requirements of the dynamic evolution of the simulated road network, an editor for the dynamic road network is built based on spatial closest neighbor matching. The case study illustrates the process of building the simulated road network and environment in the old city zone of Suzhou. Real-world examples demonstrate that the data-based ARNG approach provided in this study is highly automatic and scalable.

Keywords: data-based framework; road network modeling; micro traffic simulation; multi-modal traffic

1. Introduction

Intelligent traffic technology has gradually replaced traditional traffic technology [1,2]. The twinning of the actual road environment and traffic conditions in the digital world has become a popular direction for the development of modern intelligent transportation technology, especially traffic simulation. Significantly, the road network model affects the difference between traffic conditions in the simulation and the real world. Road network generation, as the foundational module of traffic simulation, is required for the simulation to reflect the actual road network information accurately. The important role of traffic simulation is to observe whether the traffic situation improves after imposing potential traffic management measures (such as road closure and open emergency lanes) according to the restored realistic traffic flow [3]. Therefore, the road network generation method needs to abstract information such as intersections, road alignments and lane conditions in reality into mathematical models and load them into the digital world.

The traditional basic road network model has been studied relatively maturely, and it can be generated and applied to various traffic simulation tools. However, most of the existing road network generation methods are manual and discontinuous. For example, a simulation scenario is that a certain road section actually needs to be partially closed for maintenance. The premise that this scenario needs to be reproduced is that the road network needs to be adjusted. With the proliferation of perceptual devices such as cameras, gantries and radar-video fusion devices, along with the development of data-based technical methods [4], it can be argued that future traffic simulation will be more capable of meeting the higher requirements for rapid calculation and accurate simulation, which means that road network generation methods gradually need to develop in the direction of automation, fusion of multi-source data and high scalability. Consequently, the primary objective of this paper is to investigate a data-based multi-modal traffic microsimulation framework for an automatic road network generation (ARNG) approach that can precisely adapt to actual traffic and more accurately depict the actual traffic condition. The contribution of this paper is to improve the efficiency and functionality of road network construction in traffic simulation, which is different from the traditional manual road network construction method. Combined with diverse map data, the road network topology is corrected, in place of manual adjustment. According to the actual multi-mode operation data, a multi-mode road network including bus or subway transit is constructed. In addition, the designed road network generation framework meets the needs of dynamic adjustment of the road network in simulation.

The remainder of the paper is formulated as follows: The basic concepts of the road network model and related research are first introduced. Then, the methodology of the ARNG framework mainly consists of a basic simulation of road network integration, multi-modal transportation road network expansion and road network dynamics modification. Further, a case study is analyzed using relevant experimental data, and conclusions are discussed.

2. Related works

Typically, the road network model comprises four fundamental components (nodes, edges, connections and lanes) in traffic micro-simulation. Nodes are the convergence and bifurcation locations of roads, the beginning and end points of road segments and the sites where numerous roads can link [5]. For instance, when a node joins four road segments, it reflects the junction of those roads in the actual road network. In addition, when a node joins three or more road segments, it can be subdivided into signalized and unsignalized junctions. A road connection may contain one or more lanes and represents the core structure of a road network by connecting nodes. Lanes are directed paths within a road connection along which cars may go. In order to mimic the actual road network, the road network model within the simulation program needs to additionally reflect the direction of vehicle traffic, various turning limitation tactics at junctions and other data. Consequently, the connection is a crucial component of the road network model. Connections are used to establish the connection of road connections or lanes that are linked to the same node, and vehicles can only access the road connections or lanes to which they are connected at the end of the road connections or lanes. Figure 1 shows the structure of the base simulation road network. In this case, there are five nodes (n_1, n_2, n_3, n_4, n_5) and four edges (e_1, e_2, e_3, e_4). In addition, the lane element is attached to the edge: e.g., the e_1 section has three specific lanes, l_1^1, l_1^2 and l_1^3. The connection has a total of six based on all lane relationships: e.g., c_2 describes the straight ahead state from lane l_1^1 to lane l_4^1.

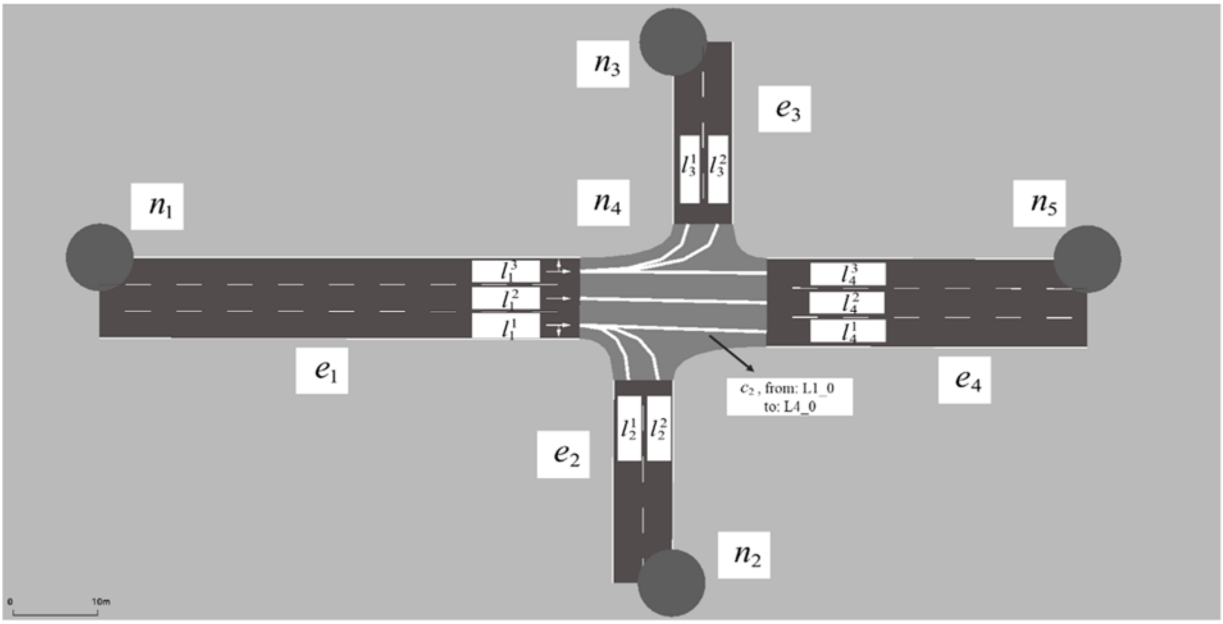


Figure 1. Schematic diagram of the basic structure of the road network**.**

There are two main methods to construct the basic road network for traffic simulation: One is to achieve it by manual construction, and the other is to achieve it by transforming electronic map data. First, commonly-used simulation software only sets traffic simulation roads by manually constructing road networks, which is a laborious process. In order to bypass the laborious process of manually building road networks, several researchers have developed diverse road network models. Jing et al. [6] suggested a template-based model for the development of road network data, although the model is primarily concerned with the reproduction of simulation scenarios and does not depict the road topological linkages in depth. Chen et al. [7] has presented a user-editable model for the development of road networks that does not account for the topological linkages between roads. The ARNG approach overcomes the problem of manually constructing road networks and minimizes the effort associated with the production of road networks using traffic simulation software. The ARNG approach based on computer aided design (CAD) drawings has trouble displaying the topological relationships of real road networks. There is no road network generation approach appropriate for the vast majority of traffic simulation software.

The current types of electronic maps include geographic information system (GIS) electronic maps, point cloud data maps, open street map (OSM) maps and others. These digitized maps give adequate information for the creation of traffic simulation road networks, but they cannot be utilized as simulation road networks themselves. Consequently, there are also several academics that seek the speedy creation of urban road networks by completely extracting information from computerized maps. Wilkie [8] provided an approach for optimizing GIS data that converted coarse and insufficient GIS road network data into a high-detail road network model. Wang et al. [9] presented a technique for creating a 3D road network from 2D GIS data. The method of road network construction based on electronic maps can expedite the construction of large-scale traffic road networks. However, this method cannot accurately reflect the topological relationships of actual road networks, and the degree of road network refinement is highly dependent on the quality of the obtained electronic maps. In addition, different types of electronic maps utilize distinct storage formats for road network features, making it challenging to establish a single road network transformation standard and procedure.

In addition, some researchers have constructed and dynamically edited traffic networks using semantic modeling techniques. In general, semantics refers to the interpretation of computer symbols, which is a crucial means for connecting computer language and reality. Semantic modeling of road networks refers to the process of generating road networks using specific mathematical geometric methods after extracting sufficient traffic scene information for data collected from actual road traffic scenes, such as road median position, lane width and road curvature, among others. Nishida et al. [10] constructed a road network model that applied semantic modeling to scenario modeling. However, road network models applied to scenario modeling do not emphasize the road network's topology and hence cannot be easily transferred to the subject of traffic simulation. Mao et al. [11] enhanced the road network model used for scenario modeling by including road topological data in a traffic road network model for traffic simulation. However, the created model does not permit dynamic editing changes, such as the addition of new lanes and road widening. The traffic road network model based on the semantic modeling method primarily uses the traffic semantic information obtained within the road scene to carry out the road network construction work, and the quality of road network generation is closely correlated with the quality of the data. In addition, even though this technology enables dynamic change of a road traffic network and eliminates the shortcomings of traditional simulation, such as the requirement to re-simulate after adding or removing lanes, the efficiency of its dynamic editing of the road network is poor.

The problem with generating a road network from a single map information source is that the road network may not correspond to the actual roads. Therefore, a road network construction method based on multi-source data fusion is crucial for determining the authenticity of the road network and updating the road network. Ross et al. [12] proposed an algorithmic study to optimize the centerline of the original road network based on vehicle trajectory data. Newson and Krumm [13] were the first to apply a Hidden Markov Model for map matching. Zhu et al. [14] suggested a matching algorithm based on the segmentation of trajectories. Yin and Wolfson [15] suggested a matching method based on de-sorting to circumvent the issue of disconnected matching results brought by examining simply road geometry.

The initial difficulty of road network construction based on multi-source data lies in the problem of multi-source road network matching. Previous researchers have proposed various road network matching methods based on spatial similarity, mathematical models and heuristic algorithms [16–18]. These methods can significantly improve the accuracy of road network matching, and some researchers have also integrated previous work on road network matching to realize the functions of updating the road network topological relationships, updating the electronic map information and filling in some missing fields, so that the road network structure in the simulation software more accurately reflects the real road network's shape and characteristics. However, recreating or enhancing road network information based on vehicle trajectory data necessitates the processing of enormous amounts of data and has the issue of using computer resources.

In this paper, a data-based framework for ARNG to construct a multi-modal traffic simulation road network environment is provided to solve the issues. Considering different input data requirements, the basic road network fusion of GIS and Open street map (OSM) electronic maps based on a spatial matching method is studied. Next, the multi-modal traffic data is imported into the simulation base road network based on multi-modal traffic data to form a multi-modal traffic simulation road network. Finally, the dynamic interruption of the road network based on the nearest neighbor matching method is implemented to have a better understanding of the impact of road network interruptions on multi-modal traffic simulation. The dynamic interruption of the road network based on the closest neighbor matching approach enables dynamic editing of the road network and improves the simulation road network's scalability.

3. Methodology

3.1. Basic simulation road network integration

The node model employed by the e-map road network is straightforward, condensed and frequently utilized. However, there is a shortcoming in that the content of road information is not fully expressed. Consequently, it is unable to accurately describe the traffic attribute information, limiting its scalability and compatibility [19]. In this study, the topology of the microsimulation road network is defined using the Node-Edge-Lane-Connection road network model. The road network topology is shown in Figure 2, which contains directed graphs of $G=(N, E, L, C)$:

$$N=\{n_i=(Latitude, Logitude)\} \tag{1}$$

where N represents the set of coordinates of all roadway nodes in G. A node is a break in an edge's traffic organization, with the node's serial number, latitude and longitude coordinates and the node's attributes. The node's attributes specify whether it is a traffic light.

$$E=\{e_j=\langle n_p, n_q\rangle \mid n_p, n_q \in N\} \tag{2}$$

where E denotes the set of all edges of G. np and nq are, respectively, the beginning and ending nodes of the edge j. The traffic qualities carried on the edge include the maximum speed permitted for vehicles, length and limits.

$$L=\{l_k^x \mid k \in E, x=1,2,...,X_k\} \tag{3}$$

where L denotes the lane information contained in each edge in the edge set. X_k is the maximum number of lanes corresponding to edge k.

$$C=\{c_m=\langle l_f, l_g\rangle \mid l_f, l_g \in L\} \tag{4}$$

The connection C is an indicator of linking one lane to the next at a certain node; its primary role is to instruct the vehicle to go straight, turn right or turn left upon entering a junction.

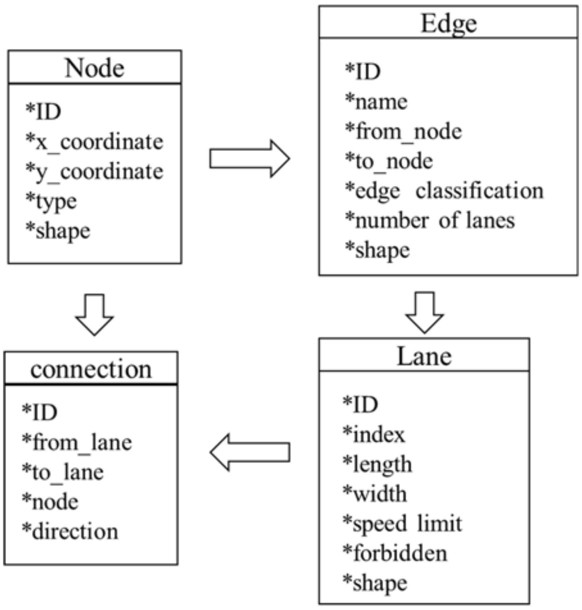


Figure 2. Microscopic traffic simulation road network topology information.

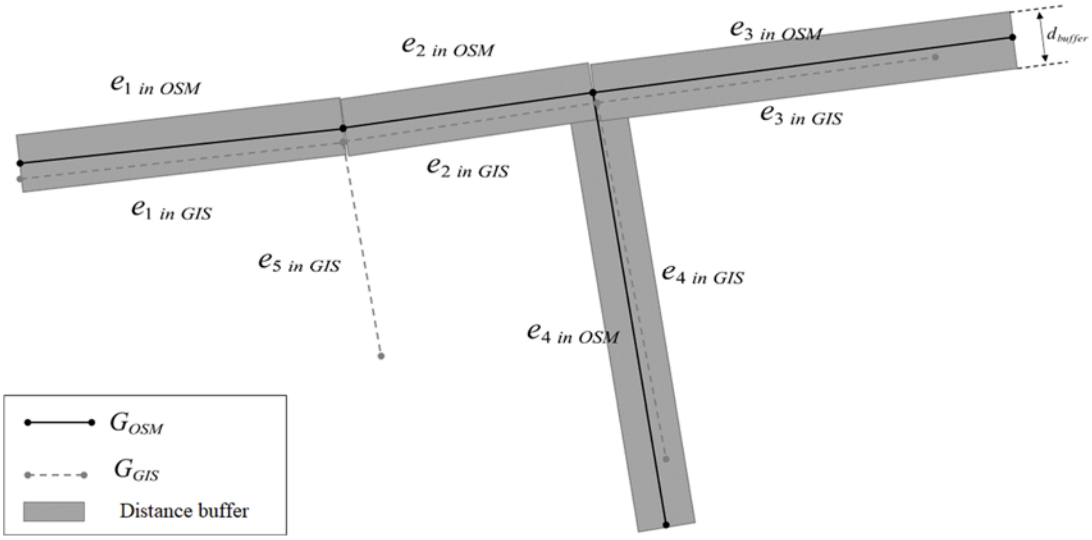


Figure 3. Basic simulation road network fusion.

Current sources of fundamental modeling road networks are mostly OSM and GIS electronic maps, each of which have their own benefits and drawbacks. OSM map data has the benefit of being easily accessible and having a tried-and-true road categorization system. The majority of simulation software supports the input of OSM maps; however, the level of precision is relatively low. Due to the range of sources, GIS map data can reflect improved map information, such as the ban of traffic information [20]. However, because the data format is closed, it is impossible to read it as input for the simulated road network. In this paper, geographical matching is performed for both OSM and GIS road network maps in order to preserve a more refined road network. The primary study approaches for determining the topological link between OSM and GIS road networks are spatial connectedness and matching.

The development of a rectangular distance buffer for the baseline collection of edges $E_{baseline}$ in the network topology is an important tool for fusing the base simulation road network topology. The length of the buffer area corresponds to the length of the edge, while the width corresponds to the distance selected for the buffer d_{buffer}, using the centerline of each edge as a reference. To determine if the associated edge exists in the collection of edges $E_{correspond}$ to be matched to the network, the matching degree H is computed using the equation below:

$$H = \frac{S_{e_i}}{S_{buffer\ in\ e_j}},\ e_i \in E_{correspond},\ e_j \in E_{baseline} \tag{5}$$

$$S_{buffer\ in\ e_j} = d_{e_j} * d_{buffer},\ e_j \in E_{baseline} \tag{6}$$

where $S_{buffer\ in\ e_j}$ is the benchmark road network's buffer area, and S_{e_i} is the area of prospective edges in the network to be matched. When $H \geq H^*$ (where H^* is the set matching degree threshold), e_i and e_j are matched. As seen in Figure 3, the OSM road network is employed as the baseline road network topology G_{OSM}, and a distance buffer zone is created for it. In Figure 3, $e_1, e_2, e_3, e_4 \in G_{GIS}$ may all be matched, but e_5 has no matching edge in G_{OSM}. The following are the main methodological processes.

Road network Parsing: On the basis of the electronic map data of the research region, parsing is performed, and information is created on the elements of nodes, road sections, turning connections and lanes of the simulation base road network, resulting in road network topology G_{OSM} and G_{GIS}.

Road Segment Classification: On the basis of OSM road section types, the road network of various road classes is filtered hierarchically, and their connectivity is verified. Sub-networks are deleted in accordance with the principle of retaining only the largest weakly connected networks, and intersections with overlapping N radii are redundantly merged to achieve an automatic hierarchical filtering process for the simulation base road network.

Distance buffer setting: To simulate the basic road network as a buffer, the GIS map road network and the simulation of the basic road network for spatial links, the connection of the topological relationship selected to contain the relationship, to achieve one-to-one correspondence between the road sections of the GIS map road network and the simulation of the basic road network, the GIS map road network road information can be expanded to the simulation of the basic road network.

Matching Information Fusion: The missing information in the simulation base road network, including lane data, speed limit, one-way lane and lane width, is completed based on the matching of road section information, and the simulation base road network is produced.

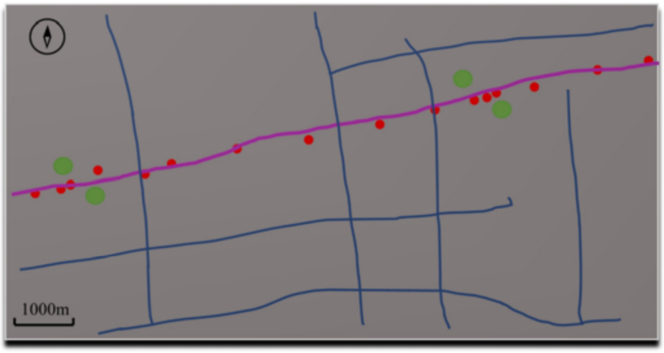
3.2. Multi-modal transportation road network loading

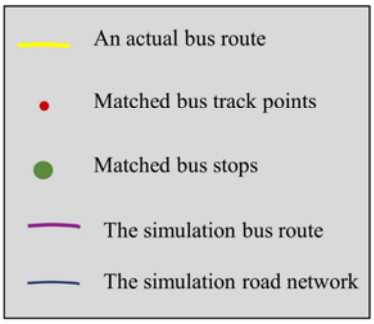
To further enhance and recreate urban multi-modal traffic situations, this paper suggests supporting multi-functional data information input of numerous aspects, such as public transit data and bayonet data. By combining traffic-related data from multiple sources, a strong data foundation is established for realistic and accurate multimodal urban traffic simulations [21,22]. Matching and loading public transportation data into the basic simulated road network to construct a multi-modal traffic simulation scenario is a key step in the ARNG method proposed in this paper.

Table 1. Introduction of public transportation data fields.

Field name	Data type	Remarks
Line ID	String	The name given to each route
Line name	String	The line distinguishing up and down, e.g., Line39 (Jinshan Road station - South Bus Station)
Bus stop id	String	The name given to each route
Bus stop name	String	The station, such as South Bus Station Bus Interchange Hub
Bus stop longitude	Float	Longitude information of bus stop
Bus stop latitude	Float	Latitude information of bus stop
Site serial number	Integer	The order in which buses reach their stops
trajectory longitude	Float	Longitude information of bus trajectory
trajectory latitude	Float	Latitude information of bus trajectory

(a) An example of an electronic map and an actual bus route





(b) The corresponding example of the simulated road network, bus trajectories, stops and routes

Figure 4. Illustration of multi-modal bus and simulated road network matching.

Table 1 presents the commonly used fields for public transport data. The latitude and longitude coordinates of the bus stop are transformed to (x, y) simulation space coordinates, and the resultant bus stop information is matched to the nearest road in the simulation road network using the nearest neighbour matching (NNM) algorithm. The bus stop location and lane number are determined by converting the latitude and longitude coordinates of the bus stop into (x, y) coordinates in the simulation space, returning all the edges within the radius of (x, y) as the center and selecting the most appropriate edge as the edge where the bus stop is located. The purpose of integrating many stations in a specific neighborhood into one station is accomplished by calculating the distance between stations.

Figure 4(a) shows the trajectory information of a real bus line. According to the trajectory point and bus station data, the multi-modal road network matching method can determine the connecting road between each trajectory point and construct the matching bus line in the simulated road network, as shown in Figure 4(b).

3.3. Road network dynamics modification

Road networks are dynamic in nature. In actual life, owing to traffic accidents, road construction, etc., it is often necessary to block the road in the simulated road network [23,24]. However, the start and end of the road within the simulated network is often different from the start and end of the road to be blocked. Thus, it is necessary to interrupt the simulated road at the designated place first. Figure 5 depicts the dynamic interruption's process.

Single Point Interrupt Method (SPIM): The nearest edge e_i is matched based on the latitude and longitude data of the places to be interrupted using the nearest neighbor technique for a specified road network topology $G = (N, E, L, C)$. The form of each edge lane is preserved in a list by reading the shape characteristics of the acquired section's child lanes. The contours of all edge lanes are recorded in a list. Each lane is trimmed using linear interpolation according to a specified distance or scale. The new node n_{cut} is created at the shape's break position. To ensure the connectedness of the road network, new connections are made at the given n_{cut} based on lane access.

The Two-Segment Break Rule: The two-segment break rule is used when the break's beginning and ending locations correspond to two distinct parts. Using SPIM, the two-segment break rule is applied to separate the two matching edges. After the break, each part will be divided into two new subsections.

The three-segment break rule: If the match results in the same edge, the three-segment break rule is used, and SPIM divides the matched edge into three subsections by dividing it twice.

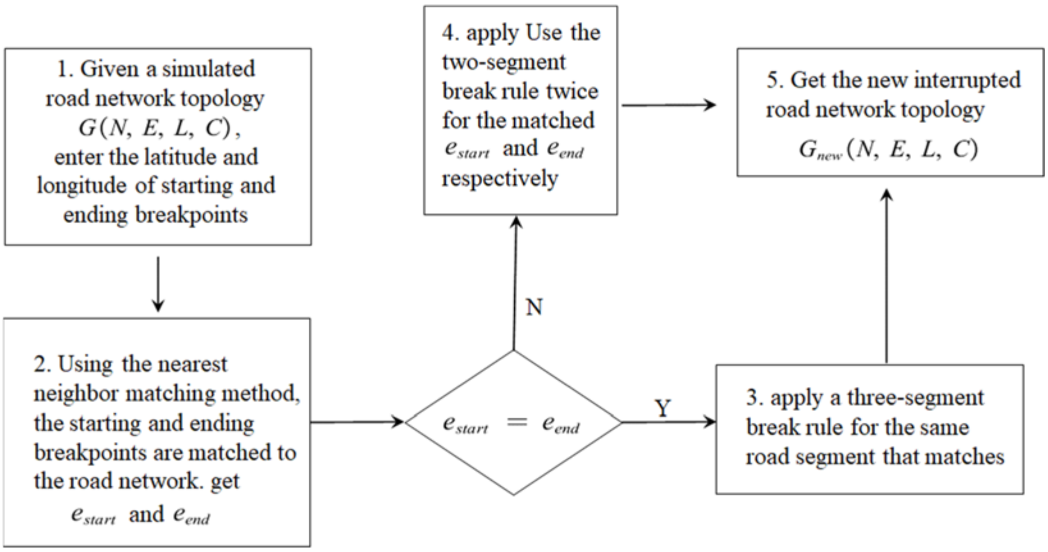


Figure 5. Dynamic road network disruption procedure in simulation.

4. Case study

This paper is based on the Simulation of Urban Mobility (SUMO) simulation platform [25], which supports large scale complex road network inputs and traffic patterns such as bus, pedestrian and subway traffic, and it has a powerful interface that can be combined flexibly with existing libraries (e.g., Tensorflow). etc., given a solid foundation and conditions for secondary growth. Currently, the road network structure in SUMO is composed of four fundamental components: edge, junction, connection and lane. The road network builder may construct the road network by defining these four fundamental components. Each of the four fundamental components is loaded with qualities.

Edge: In SUMO, edges mainly include road name (ID), edge start (from), edge end (to), road importance (priority), function (function) and road attributes (type). The specific meaning of each attribute is shown in Table 2.

Table 2. Description table of road section attributes.

Attribute	Type	Remarks
ID	String	Road segment name with uniqueness
from	String	The starting point of the road segment, which is the node ID
to	String	The end of the road segment, named node ID
priority	Integer	Indicates the importance of the road
function	Normal, internal	Indicates road section function, default is normal
type	String	Defining road attributes

The function specifies edge values, including normal, connection, internal, crossing and walking area, among others. Normal signifies a typical edge, such as a city street or motorway. Internal refers to an edge within an intersection, and the internal edge type is a node-internal road. Crossing represents a pedestrian crossing at a junction, whereas walking area represents a pedestrian zone.

The type is used to specify the road's properties, such as "highway motorway," "highway secondary," etc., which are used to decide the speed limit, the number of lanes, the types of vehicles operating on the road and other information.

Junction: In SUMO, a junction is represented as a junction at an intersection or roadway, and it has a node name (ID), a horizontal coordinate (x), a vertical coordinate (y), an intersection connection lane (intLanes), an internal intersection lane (incLanes), etc. The meaning of each attribute is shown in Table 3.

Table 3. Description table of node attributes.

Attribute	Type	Remarks
ID	String	Node name with uniqueness
x	Float	Horizontal coordinate of the node
y	Float	Vertical coordinate of the node
intLanes	List	Intersection connected lanes
Inclanes	List	Internal lanes of intersections

Connection: The connection specifies how an intersection's inlet and exit lanes are related. Inlet lane (from), outlet lane (to), inlet lane (fromLane), outlet lane (toLane), signal light (tl) and direction of connection are the fundamental characteristics (dir). The definitions of each attribute are provided in Table 4.

Table 4. Description table of steering relationship attributes.

Attribute	Type	Remarks
from	String	Connected inlet sections
to	String	Connected exit sections
fromLane	Index	Index of the import lane
toLane	Index	Index of exit lanes
via	String	Intersection internal lane (internal type)
dir	Enumeration	Connection Direction
tl	String	Controls the traffic light ID at that point

Here, dir has the following options: s for straight ahead, t for turn, l for left, r for right, L for partial left, R for partial right and invalid for no direction.

Lane: The lane is the structure of the road network contained within the edge, which mainly includes the following attributes: lane name (ID), index (index), allowed vehicle type (allow), prohibited vehicle type (disallow), speed limit (speed), lane length (length), lane width (width), geometric position (shape). The meaning of each attribute is shown in Table 5.

Table 5. Description table of lane attributes.

Attribute	Type	Remarks
id	String	Lane name with uniqueness
index	Integer	Lane number
allow	List	Types of vehicles allowed to pass
disallow	List	Types of vehicles prohibited from passing
speed	Float	Maximum speed limit
length	Float	Length of lanes
width	Float	Lane width
shape	Float	Lane centerline coordinates

In conclusion, SUMO may be used to rapidly construct a road network by specifying attributes for the four fundamental parts of edges, nodes, connections and lanes. The number of lanes can only be calibrated by the road type of OSM. It supports the import of various types of electronic maps, but the various input forms cannot complement each other's correction. The road and intersection IDs are unclear, which is not conducive to the secondary packaging of the intelligent body training environment. The electronic map of SHP can make up for the defects of osm. As shown in Table 6, the electronic map of SHP can describe the detailed information of a lane. By combining SHP and OSM electronic maps, this project enables the batch adjustment of lane numbers on the net road network derived from OSM maps.

Single-point prediction and group clustering are the core of smart parking system construction. Emerging technologies for edge computing, AI algorithms, AI maps and spatiotemporal big data provide technical support for smart parking systems. A prediction for the near future is that a map of smart parking data can be constructed through the integration of various parking resources in a city. Optimal solutions for parking space resource allocation can be obtained.

Table 6. Example of the original SHP file containing fields for the old city zone of Suzhou.

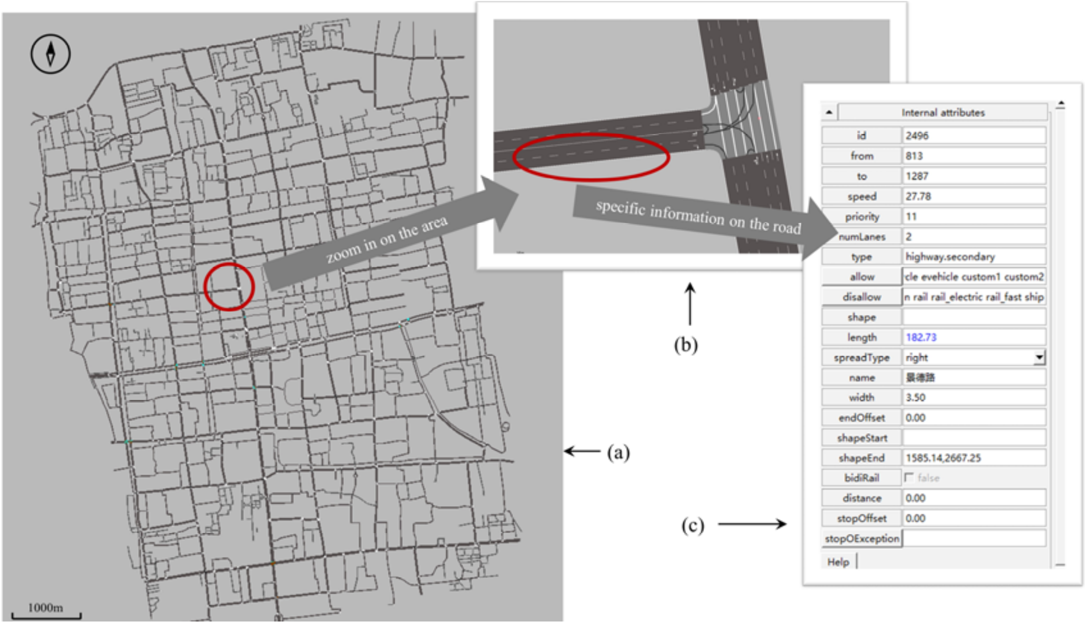
Id	name chn	Fnode	Tnode	P_lanes	n_lanes	Direction
0	Xumen street	10	7	1	1	1

Figure 6. The road network data for OSM and GIS map in the old city zone of Suzhou.

In this paper, the old city zone of Suzhou is chosen as the study area, and Figure 6 depicts the underlying road network data for OSM and GIS maps. The area is a typical traffic road network of 17 square kilometers with 1357 nodes and 3504 edges, because the road access to and from the area is well-distributed. The main road inside the area is in the shape of a cross, but the road density is high. Traffic congestion in this area occurs from time to time due to low road capacity but high traffic flow. As seen in Table 7, the original GIS map (Shp file) provides precise road information such as the number of forward and reverse lanes, meticulously mapped junction data and other fields. It includes information such as name_chn (street name), p_lanes (number of forward lanes), n_lanes (number of reverse lanes), direction (lane direction), etc. Compared to the OSM road network, the GIS road network of the old city zone of Suzhou is more refined and reflects the actual city road network more precisely. As the GIS road network is manually drawn, however, there are no standardized fields; therefore, with the OSM road network, standardized fields such as the OSM road section types are matched with the GIS road network. This refines the road network in the city by compensating for the inadequate descriptiveness of the OSM road network and the lack of homogeneity in the fields of the SHP road network.

First, there is the development of a basic road network simulation based on electronic map data of the research region.

The road types in OSM are then filtered for retention. OSM roads are primarily lengthy and complete, while GIS roads are primarily short. The fragmented roads must be buffered with OSM data (similar to broadening the linear data into faceted data). The length of the buffer may be checked, and d_buffer = 20 m, which is ultimately determined to be the most suitable value (a too small value yields a large number of roads that cannot be matched, while a too large value yields a matching error). After that, spatial linkage is conducted. The topology of the connection is chosen to include the number of lanes attribute in the surface data, and the lane attribute of the buffer is then added to OSM using the spatial link. Figure 7 depicts the micro-simulation network loaded into the SUMO simulation after OSM and GIS map data integration. Figure 7(a) is the simulated road network of the entire old city zone of Suzhou. To view the road conditions in a more refined manner, Figure 7(b) randomly selects the enlarged situation of a certain road segment. Figure 7(c) shows precise road segment information that is unavailable in OSM but is available in GIS, such as the number of lanes. Additionally, the OSM lane categorization "highway secondary" is retained.

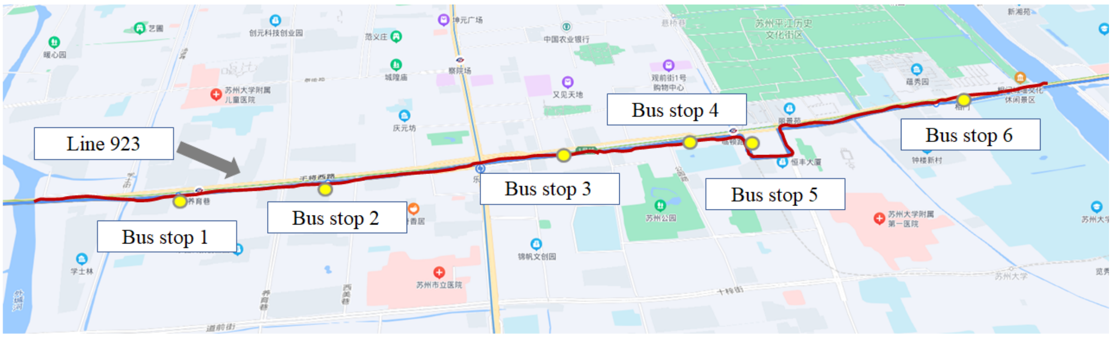


Internal attributes	
id	2496
from	813
to	1287
speed	27.78
priority	11
numLanes	2
type	highway.secondary
allow	cle evehicle custom1 custom2
disallow	n rail rail_electric rail_fast ship
shape	
length	182.73
spreadType	right
name	景德路
width	3.50
endOffset	0.00
shapeStart	
shapeEnd	1585.14,2667.25
bidiRail	☐ false
distance	0.00
stopOffset	0.00
stopOException	

Figure 7. Basic simulation road network results. (a) The micro-simulation road network of the old city zone of Suzhou after the fusion of the two-map data; (b) Example of a specific study area; (c) Detailed information about the specific road segment after road network fusion.

Open source Gaode Map provides access to bus data. Line 923, Line 1, etc., which travel through the old city zone of Suzhou, were selected. These routes' information, stop information and GPS data are gathered through crawling. Following the Section 3.2 procedure, a multi-modal simulation of the road network environment can be constructed. Figure 8(a) demonstrates that Line 923 has a total of six bus stops in the ancient city area of Suzhou. Line 923 follows the red line through these six stops. In accordance with reality, the simulated road network contains the same six stops, and the simulated path of Line 923, as seen by the yellow line in Figure 8(b), is likewise consistent.

For dynamic editing of the road network, interrupting the network requires the input of data for the interrupting points. Two sets of interruption data are input, as shown in Table 7. The two data sets are then utilized in the same method as in Section 3.3 in order to produce the findings depicted in Figure 9. Because the start and end points of break point 1 are linked to the same edge, the three-segment rule is activated. Because the two nodes at break point 2 correspond to separate road segments, the Two-Segment Break Rule is utilized. After such an interruption, the simulation may be repeated to do a dynamic extrapolation of the highway ban for the damaged roadway.



(a) The actual route and station of Line 923 in the ancient city area of Suzhou

(b) The simulated route and station of Line 923 in SUMO

Figure 8. Comparison of actual and simulated results of Line 923.

Table 7. Example of Breakpoint data.

id	type	Longitude	Latitude
1	start	120.614349	31.314691
1	end	120.615916	31.314937
2	start	120.616491	31.315625
2	end	120.616457	31.314486

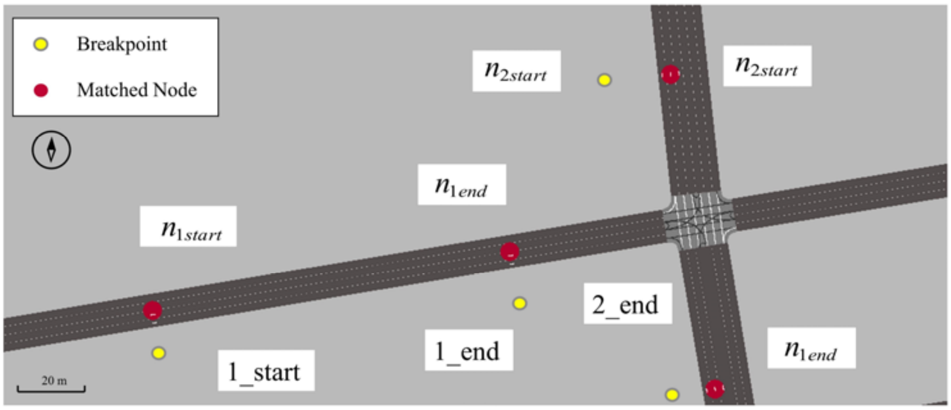


Figure 9. Comparison of actual and simulated results of Line 923.

5. Conclusions

This paper enhances the simulation road network environment for existing traffic simulation tools, and it develops an automatic simulation road network environment driven by multi-source data. First, according to the simulation road network of different road grades, a road network fusion method of OSM and GIS map data is proposed. This method can retain the multi-source road network information and provide a refined simulated road network model for the ARNG method. Second, based on the real bus data, the multi-modal traffic operation environment is matched for the simulated road network. Finally, to endow ARNG with extensibility, a data-based road network dynamic editing module is proposed. This function can meet an important requirement in simulating traffic simulation, that is, simulating the traffic operation state caused by road partition caused by road construction or closure. Through the case in the old city zone of Suzhou, the practicability and accuracy of the ARNG method are proved.

This paper focuses on the automatic generation of a traffic simulation road network environment based on a multi-source data-based approach. The key point is to solve the problems of low efficiency caused by the need to build the basic road network manually, the unreality of the simulation environment, the poor quality of the simulation scene and the difficulty of supporting the subsequent traffic control strategy. In follow-up research, based on the actual problems in road network generation, the data-based framework for the ARNG approach will be further expanded to build the simulation road network environment.

Conflict of interest

The authors declare there is no conflict of interest.

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