MODELING AND IMPLEMENTATION OF NAVIGABLE GEOGRAPHIC FRAMEWORK DATA —— CONSTRUCTION OF ROAD NETWORK BASED ON FUNDAMENTAL GEOGRAPHIC DATA

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ABSTRACT:

Navigable geographic framework data functions as the geo-spatial referencing framework that integrates traffic maneuver and POI(s). The main difference between the navigable geographic framework and the traditional fundamental geographic data is that the former emphasizes the connectivity of the road network. It should describe the logical traffic flow carried by each road element, especially around complex flyovers. This paper studies the data model of navigable geographic framework data, and proposes a method for constructing road network based on multi-scale fundamental geographic data.

1. INTRODUCTION

In the field of application of Intelligent Transportation System (ITS) and Location Based Service (LBS), navigation is currently the most widespread and successful consumer application, with huge profit already in the developed countries and huge market potential in the developing countries as China (CAO Chong 2001, 2003, ZHAO Jing 2003, ZHAO Huiping 2001).

The navigation system uses navigable geographic data as a basis. To meet the requirement of navigation application, it is necessary to modeling traffic related features and various traffic restrictions. Now the International Organization for Standardization (ISO) issued the international standard which specifies the conceptual data model and data exchange format for the geographic databases for ITS applications, namely Intelligent transport systems – Geographic Data File (GDF) – Overall data specification (ISO 14825:2004). Based on this standard, China issued related standard accordingly, namely Data model and data exchange format for navigable spatial database (GB/T 19711-2005). There are several levels in the navigable geographic data, which are geo-framework, social or economic information, static traffic information and dynamic traffic information (JIANG Jie 2003). The level of geo-framework is the foundation of geo-spatial reference. Navigable geographic framework data functions as the geo-framework. It represents the geometry and location of road network, road furniture, place name and relative background information. Integrating social economic and traffic information with navigable geographic framework data will result in navigable geographic data. So the navigable geographic framework data is indispensable in navigation industry.

The multi-scale fundamental geographic data are the main data source in the production of navigable geographic framework data. But existing fundamental geographic data can't satisfy the requirements of navigation application. Therefore, to produce navigable geographic framework data involves lots of works of data conversion and data reconstruction, which include series of technical problems about data model conversion, information match, and so on (WANG Yanhui, etc 2004, ZHU Zhuangsheng, etc 2005). In addition, it must be considered utilizing of existing fundamental geographic data at a maximum degree. At present, the situation is that the rationalization of navigation industry requires navigable geographic framework data but the surveying and mapping sector is incapable of providing this service. It has effected the development of navigation industry in a certain extent. Therefore, the solution to produce quickly navigable geographic framework data based on fundamental geographic data is the main issue confronted by the surveying and mapping sector.

With respect to the issue, the paper proposes the data model of navigable geographic framework data, which is compliant with GDF, and emphasizes the method of construction of navigable geographic framework data based on fundamental geographic data. Section 2 analyzes the representation of road in existing fundamental geographic data and the problems that these data are applied in navigation. Section 3 defines the content and topology representation of road network in navigable geographic framework data. Section 4 proposes the construction method of road network in navigable geographic framework data based on 1:10000 and 1:50000 fundamental geographic data. Finally, the paper has the conclusion with the data production in a pilot area.

2. THE EXPRESSION OF ROAD IN FUNDAMENTAL GEOGRAPHIC DATA

As the principle part of fundamental geographic data, Digital Line Graph (DLG) is produced by national or local surveying and mapping sector with accordance with the surveying and mapping standard. It acts as the main data source in the production of navigable geographic framework data. DLG mainly describes the geo-spatial information such as topography, river, transportation, residence, vegetation and place name. The road in DLG is modeled either by polygon or by road centerline.

2.1 With the Representation of Polygon Outline

In 1:5000 or 1:10000 large scale DLG, the road is usually modeled by polygon with the outline of block, building or roadside (figure 1). In general, the main streets are outlined by roadside, and the secondary roads are outlined by block or building. Out of the digitalization of paper map, 1:10000 DLG inherits the characteristic of paper map with the emphasis on the symbol and color to represent the topography. It is not explicit for the connectivity relation of road network, as well as the attribute is not directly connected with the road element, but by the means of annotation.

With respect to the routing and drive guidance, this data does not represent the topology information in a road network. So it is incapable of using this data to implement the computation of routing and guidance or the query of road element based on network data structure.

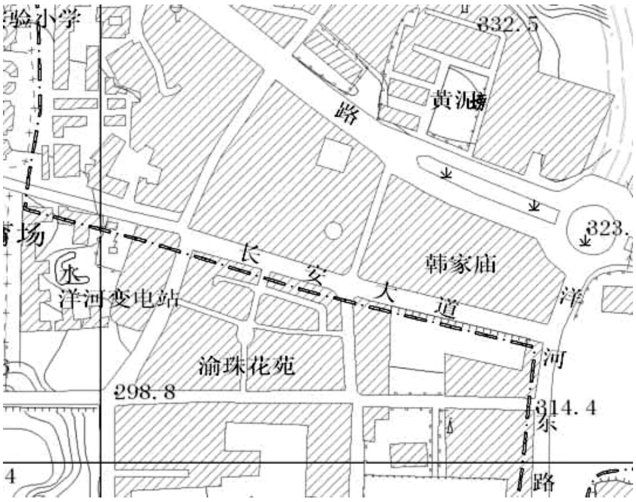


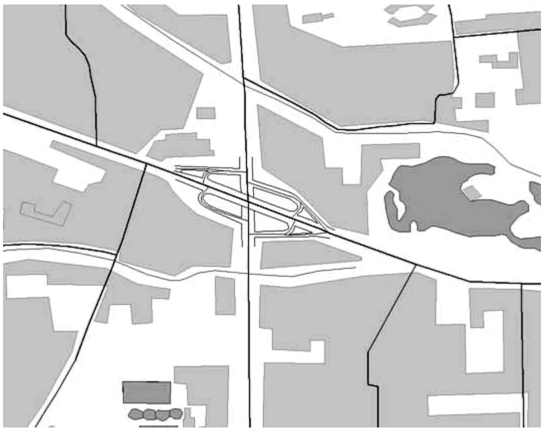
Figure 1. The representation of road in 1:10000 DLG

2.2 With the Representation of Road Centerline

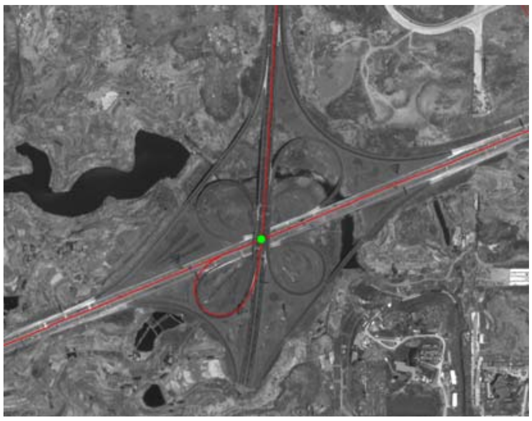
In 1:50000 or 1:250000 medium-small scale DLG, the road are usually modeled by road centerline with the planar arc-node data structure, where lines cannot cross without creating an intersection with an associated node no matter in reality two roads cross at different levels or at the same level. The intersect node cannot represent the real road connectivity correctly (Gottsegen, etc 1994, Fohl, etc 1996, Goodchild 1994, 1996, 2004). Figure 2 shows the inconsistency between the road on cloverleaf junction in reality (it can be seen from the background image) and the represented data (it can be seen from the line and point).

Moreover, the medium-small scale DLG cannot completely represents the complex flyover. Being an important component of road network, flyover is represented separately by the geometry shape or a point with spatial location. This data cannot represent the network structure on flyover and its connection with the related road. Figure 3a and figure 3b are two typical representations for flyover in 1:50000 DLG. The thick real line in figure 3a is road element, whereas the thin real line shows the cloverleaf junction. The point in figure 3b shows the center location of the cloverleaf junction.

Figure 2. The representation of road in 1:50000 DLG



(a)



(b)

Figure 3. The representation of cloverleaf junction in 1:50000 DLG

3. DATA MODEL OF NAVIGABLE GEOGRAPHIC FRAMEWORK DATA

The ISO standard GDF defines the conceptual data model of navigable geographic data applied in ITS, LBS and navigation. Real world objects or activities at a certain location are represented by 'feature' in the GDF (ISO GDF4.0). The GDF has two hierarchy levels which are feature themes and feature classes. Feature themes only distinguish between features on some basis properties. There are 13 types of themes defined in the GDF, including Road and Ferry, Administrative Areas, Named Areas, Land Cover and Use, etc. Each feature theme is subdivided into a number of feature classes, and the GDF defines 151 kinds of feature classes.

Road and Ferry feature theme is the most important content of the GDF. It defines the component, organization and topological relationship of the road network. A road network is composed of some road elements. As the smallest unit of the road network, the road element is represented by a linear section to carry the vehicular movement. One road may be represented by one or more road elements in order to represent the direction of traffic flow and the connectivity with other roads. Figure 4a shows two cross roads in reality which are separated by a physical divider respectively. Figure 4b shows the road network is constructed in accordance with the GDF.

In addition, the GDF defines two types of relationships between road element features, which are the topological relationship and the semantic relationship respectively. The topological relationship is defined by geo-spatial data structure, and the semantic relationship is defined by maneuver, time restriction and vehicle restriction to represent the traffic information between road elements.

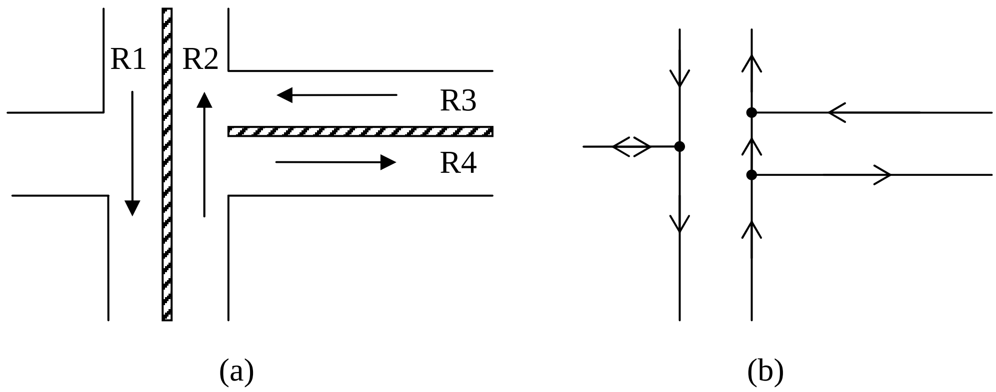


Figure 4. Representation of road network

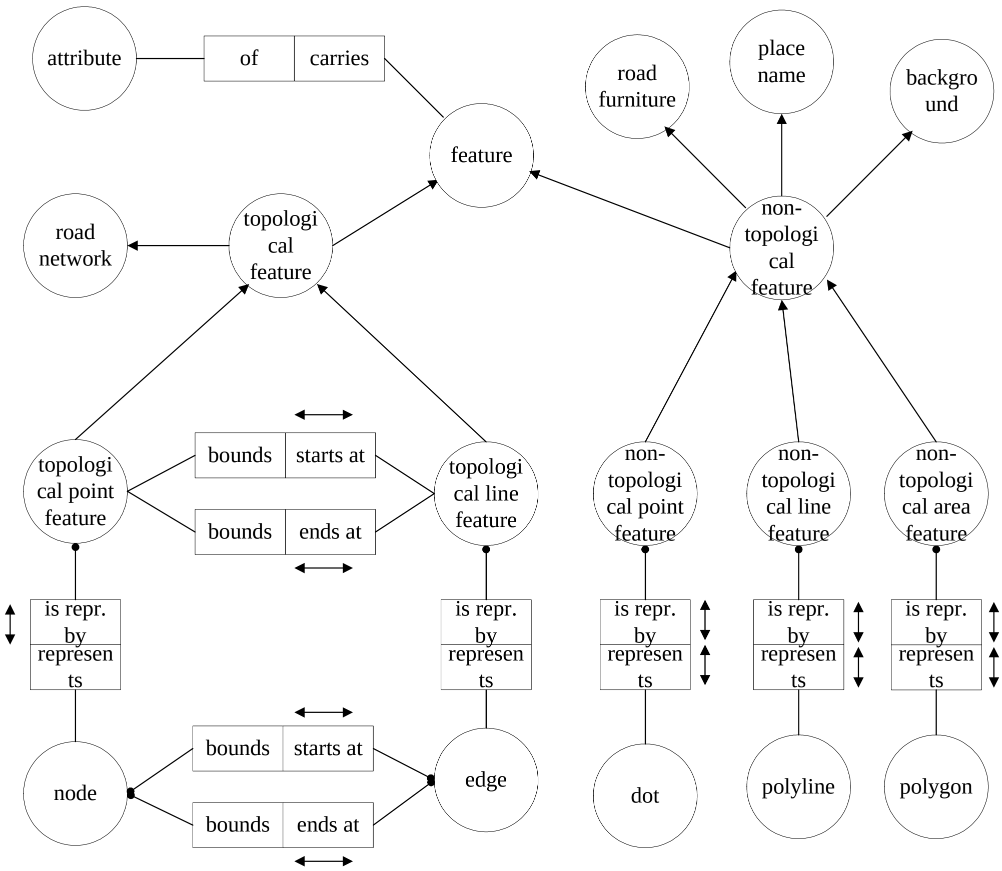


Figure 5. Data Model of Navigable Geographic Framework Data

The navigable geographic framework data functions as the geo-spatial referencing framework that integrates traffic maneuver and POI(s). It is the subset of the navigable geographic data, and mainly represents the geometry, spatial location and attributes information of the road network, road furniture, place name and background. However, the semantic relationship and POI(s) is not involved in the navigable geographic framework data. This paper designs the data model of the navigable geographic framework data based on the GDF. Figure 5 shows the data model.

The geographic objects in the real world are represented by 'feature' in this model, and properties of features are represented as attributes. Features are composed of topological features and non-topological features. The road network data is represented by the topological features which are defined by the basic building blocks nodes and edges. A topological point feature is always represented by exactly one node, a topological line feature by one or more edges. The node bounds the edge and the edge starts or ends at the node. The road furniture, place name and background data are represented by the non-topological features. In the non-topological way, the features are defined by the basic building blocks dots, polylines and polygons. Figure 5 shows that a non-topological point feature is always represented by exactly one dot, a non-topological line feature by exactly one polyline and a non-topological area feature by exactly one polygon. It can be seen that no relationships are defined between these basic building blocks to signify their non-topological characteristic.

Road network is the most important part of navigable geographic framework data. It is necessary to represent connectivity between the road elements in order to satisfy the requirements of the navigation application. According to the GDF, this paper builds the topology relationship of the road network with the no-planar connectivity topology. In this manner, topological relations between zero- and one-dimensional objects are explicitly defined, and where in reality two features cross at different levels (e.g. two roads crossing via a bridge), the edges which represent these features cross without a node being defined on the point of crossing. As it can be seen from figure 6, the road network is composed of the road element and the junction. The junction bounds the road element and the road element starts or ends at the junction. The road element should describe the logical traffic flow carried by each road that has a physical or legal divider, especially around the complex flyovers. There are three types of junctions: (1) the plane cross junction, (2) the attribute change junction, and (3) the end junction. The plane cross junction is the junction that two roads intersect at a same plane, the attribute change junction represents the variety of the roads attributes, and a road element is finished at the end junction.

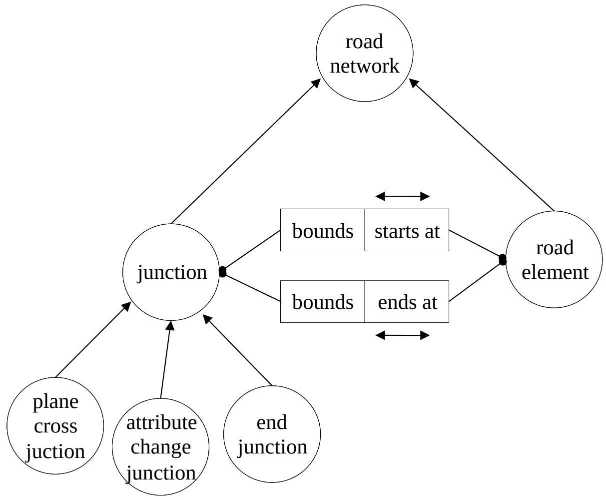
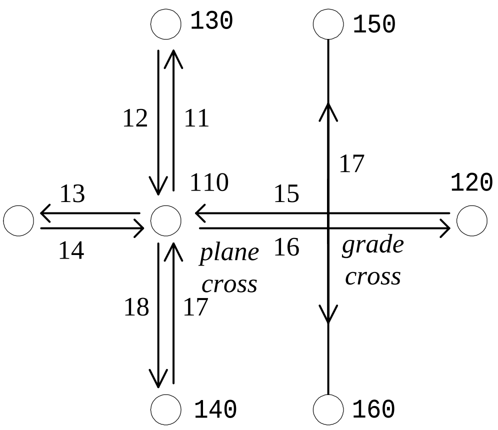


Figure 6. The data model for the road network

The features and the relationships defined in the navigable geographic framework data model are represented by the relational model. Figure 7a gives a simple example for road network construction according to the above data model, and figure 7b provides the corresponding relational structure for this network. The attribute of TrafficFlow is used to describe the direction of traffic flow allowed on a road element. The domain of this attribute as follows:

- Traffic is allowed in both directions.
- Traffic is closed in the positive direction, and open in negative direction.
- Traffic is closed in the negative direction, and open in positive direction.



(a)

Arc

ArcID	Fnode	Tnode	TrafficFlow	(Attributes)
11	110	130	1	
12	130	110	1	
……				
17	150	160	2	
……				

Node

NodeID	NodeType	(Attributes)
110	plane cross junction	
130	end junction	
……		
150	end junction	
……		

(b)

Figure 7. The logical representation of the road network data model

4. CONSTRUCTION OF THE ROAD NETWORK

Accordingly, the road network is the main part of the navigable geographic data. So the road network construction is the primary task in the production of the navigable geographic framework data based on fundamental geographic data. The main process of this task is to generate road centerlines from the fundamental geographic data, then to collect the traffic divider and flyover information from the high-resolution images or the field collection data to be integrated with the road centerlines data. Lastly, the attributes and topological relationships are processed to construct the entire road network data.

4.1 Generating the Road Centerlines from the Fundamental Geographic Data

4.1.1 Generating the Road Centerlines from the Large-scale Fundamental Geographic Data:The road is represented by the outline of building, block or roadside in the large-scale fundamental geographic data, which is always classified into different classes according to the classification and codes for the features of the topographic maps. Figure 8 is the typical example of the road representation in the 1:10000 DLG data. The outline of building or block belongs to the class of Residential Area, and the outline of roadside belongs to the class of Transportation.

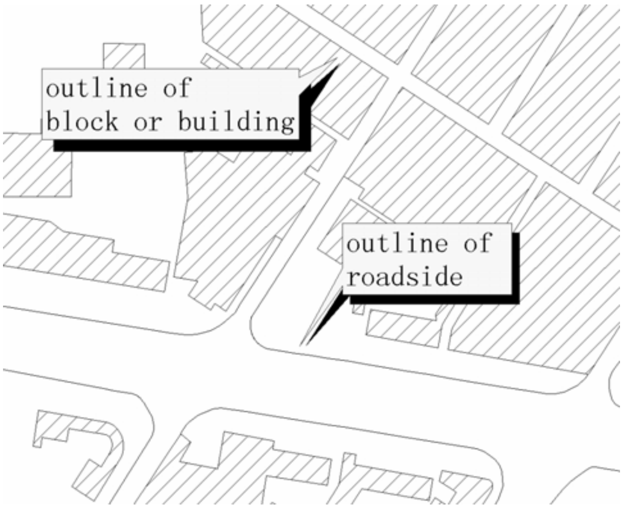


Figure 8. 1:10000 DLG data

The foundation of constructing road network from this data is to generate the road centerlines. A range of techniques and software already exist to undertake this task (Thomas 1998, Ai Tinghua, etc 2000, Hu Peng, etc 2005). The algorithm used in this paper is based on Delaunay Triangulation, and the process in detail is as follows:

- Preprocessing data. Before generating the road centerlines, it is very necessary to extract the outlines of building, block and roadside based on the classification code, and resample the lines at a finer interval (Figure 9a).
- Generating road centerlines. Computing the triangulation based on the polygons constructed by the outlines (Figure 9b). In order to capture the triangles in the roads, this paper uses P $((X1+X2+X3)/3, (Y1+Y2+Y3)/3)$ to compute the center of gravity of triangle and selects those triangles where the P point is not in the polygons of block or building. The result of removing the triangles in the blocks and buildings can be seen from Figure 9c. The triangulation produces three types of triangles: ①Triangles that share one edge with the adjacent triangle, ②Triangles that share two edges with the adjacent triangles, ③Triangles that share three edges with the adjacent triangles. Figure 9d illustrates these triangles. Each triangle plays a different role in the construction of the centerlines. The first kind of triangle is at the end of a road, and the center line will come through the middle of the shared edge and will be prolonged till joining the corresponding vertex of the triangle. The second kind of triangle will be crossed by a center line, going through the middle of the two shared edges of the triangle. The third kind of triangle is at the cross of roads, and the centre of gravity of the triangle will be the fork point, and three center lines will connect it to the middle of the three edges of the triangle. Figure 9e is the result of the road centerlines network after some necessary editing.

4.1.2 Generating the Road Centerlines from the Small-medium scale Fundamental Geographic Data:The road in the medium-small scale (1:50000) DLG is represented by the road centerlines. But the flyover is represented by the graphic lines or points. Figure 10a shows the typical example of the road and flyover represented in 1:50000 DLG. The flyover is represented by the graphic lines that only portray the figure of the flyover. Generating road centerlines from this data involves two steps. The first step is to extract the lines represent the flyover and extract the centerlines construct the roads of the flyover from these lines based on the classification codes. The second step is to integrate this data with the road data and construct the road centerlines network. Figure 10b show the result.

4.2 Supplementing the Traffic Divider and Flyover Information

In order to complete the construction of the road network, it is necessary to supplement the traffic divider and flyover information. There are three methods to implement this task. The first one is to utilize the information extracted from the available DLGs. The second one is to use the up-to-date high-resolution images or air photos to extract some required information. And the third one is to collect the necessary information in the field. Figure 9f and Figure 10c is the entire road network after supplementing the traffic flow and flyover information with the above methods.

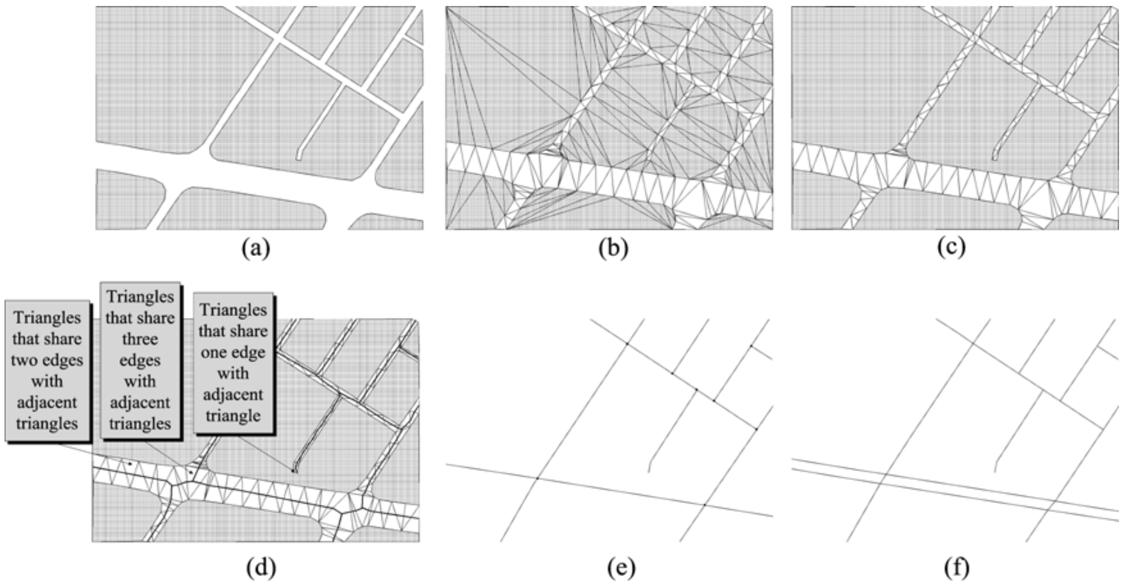


Figure 9. Constructing road network based on 1:10000 DLG

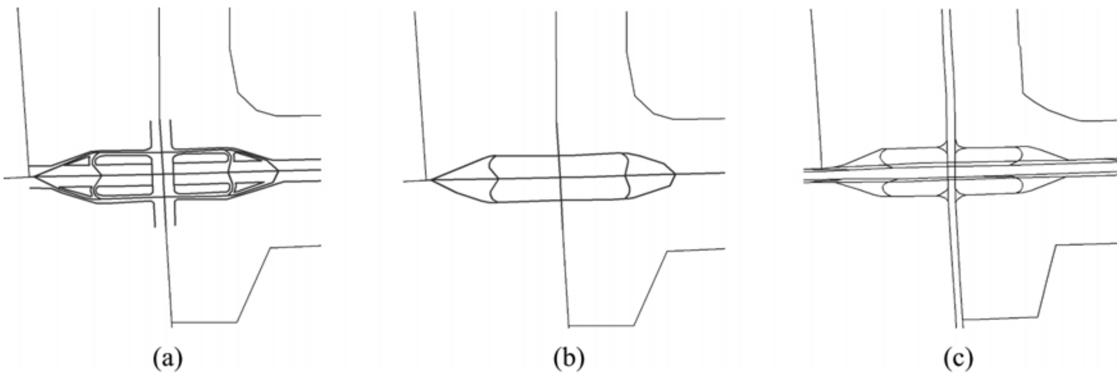


Figure 10. Constructing road network based on 1:50000DLG

4.3 Processing the Attributes and Topological Relationships

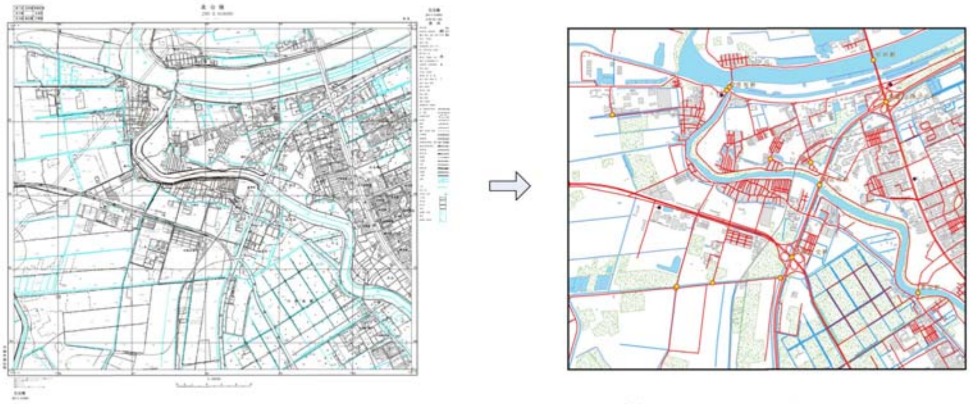
Attribute is the properties of the road elements. The navigable geographic framework data describes the road elements' attributes such as Road Name, Management Class, Technical Class, Route Number, and so on. These information can be mostly captured from the fundamental geographic data.

The logical representation of the navigable geographic framework data is implemented by the relational data model. Therefore, it is necessary to use road element's attribute to describe these information in order to represent the direction of the traffic flow and the connectivity topology relationship. In general, the number of the starting or end junctions of a road element is used to describe the connectivity of the road network. There are three types of cases to define the connectivity between two road elements. ①One road element's starting junction number is equal to the other road element's. ②One road element's end junction number is equal to the other road element's. ③One road element's end junction number is equal to the other road element's starting junction number. The numbers of the junctions are got by setting the tolerance and computing the geometry network topology.

Since it is not sufficient to use the attribute of the starting and end junction number to describe the connectivity topology of the network, the attribute of the traffic flow is used to represent to the direction of a road element. But the traffic restrictions are not involved in this attribute. There are two types of traffic flow attribute. The first one is the traffic allowed in both directions. In this case, the road is not divided by a physical or legal divider. The second one is the traffic allowed only in the positive or the negative direction. In this case, the road is divided by a physical or legal divider.

5. CONCLUSION

To expand the application of fundamental geographic data in the field of ITS and LBS, the paper proposes the model of navigable geographic framework data based on the model of GDF and the availability of existing fundamental geographic data. The paper researches the method of road network construction in navigable geographic framework data based on fundamental geographic data. It is proved that the method is effective in the data production of test area around Bo Hai, where the data production from 1:10000 and 1:50000 DLG have been finished. Figure 11 shows the comparison between fundamental geographic data and navigable geographic framework data from the test result.



（a）Digital Line Graph　　（b）Navigable Geographic Framework Data

Figure 11. The comparison from experiment results

It shows the method can reduce the workload of manual editing and promote the production efficiency. But since the fundamental geographic data is not current enough and the road information is not complete enough, production of navigable geographic framework data involves lots of data processing, which includes the data capture by the new image and field work. The following research will emphasize on the data processing, such as the automatic data processing and information extraction, and the data updating method for navigable geographic framework data.

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