Mobile map generalization approach considering user locational context

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Abstract

With the rapid development of location based services, applications of mobile map become more and more popular. Compared with other types of map, the major characteristic of mobile map is personalization. The design and production of personalized mobile map is closely related to real-time generalization which is influenced by the context of mobile environment. Among the context of mobile map use, user locational context is the most important. In this paper, we took user velocity for example, analyzed the relationship between locational context and generalization constraints and constructed the framework of mobile map generalisation. We chose road as generalize feature, implemented the road generalization operation considering user velocity.

Key words

Mobile map, Map generalization, Locational context, Velocity

1. Introduction

With the development of LBS, the content, scale and representation methods of mobile map should adaptively satisfy the requirement of individual user. Reichenbacher (2004) concluded that mobile context influence mobile map visualization. There are many facets of mobile context but location is the most important context dimension concerned with mobility. We put forward the locational context, such as the location, speed, direction of user and study the mobile map generalization considering the user locational context.

Due to the mobility of user, mobile map generalization has its own characteristics. The holistic, static idea and methods of map generalization can not fully suitable for the mobile map generalization. The characteristics of mobile map generalization could be concluded as partial, dynamic and on-demand of user. Furthermore, mobile map generalization is different from traditional map generalization at several aspects.

- The scope of the map which will be generalized cannot be clear before generalization operation carry out. It is dynamic adjusted with the user locational context. It should be limited to the region where the user being interested in.

- The map cognition of the user in mobile environment is much more objective oriented and the burden of map cognition is heavier than it is in static environment. The map after generalized should be easily understood and offer the information which the user demand.
- In mobile environment, the less interaction with the map, the more relax the user will be. Until now, map generalization process cannot be fully automatically implemented. Not only the efficiency, but also the process controlling of map generalization still need many approach.

This paper pay more attention on user locational context affecting generalization for mobile maps, especially discusses the user velocity as a parameter for deciding generalization level. We study the relationship between the locational context and generalization constraint, put forward a framework of mobile map generalization. The paper took part of the road network of Nanjing in China as example and implemented different level of selection and simplification to the roads considering the user speed.

2. User locational context and mobile map generalization framework

Reichenbacher (2004) offered a generic context model for mobile cartography and the context model included user, information, activity, system and situation. As location is the most important context dimension, he pointed out that location information is related to a position and denotes different kinds or levels of granularity with distinct ranges of values. Map generalization is used to control variable delivery of geographic information at different scales and mobile map generalization should offer on-demand geographic information related to the user activity. A conceptual framework about activity and context for mobile geoservices is given by Dransch (2004) after a careful theoretical analysis. Mobile geoservices have to take into account the alterations of user position, surroundings and also the activities and adapt the presented information to the different context and activity.

2.1 The concept of locational context

Dransch (2004) gave three descriptions for space. Location is always defined in a particular system to describe space. The most common are geographical and geodetical coordinate systems that give the absolute location of an object. Another idea of space is a more topological description of space where location is not considered in an absolute sense but in relation to other objects. Both concepts treat space and location from a mathematical point of view. The third one regards space as spatial structure that is arranged by persons and their activity. According to this concept space is only determined by activities, they form specific spatial area, the physical objects in these areas get importance and meaning only through an acting person and his or her action (Werlen,1997).

Geoservices should support the mathematical as well as the human-related concepts of space. Mathematical concepts are necessary to fix a person's absolute or relative spatial position.A more human-related idea of space can help to determine personalized, egocentric activity areas, e.g. "activity zones" or "social zones " (Reichenbacher 2004,von Hunolstein and Zipf 2003).

The influence factor of traditional generalization includes the usage of map, scale, mapping region and map data. Mobile map generalization should also consider the user locational context. What is user locational context? User locational context could be understood as situation of user which combines the location and time together. It is understood of being situated in a spatio-temporal reference system. It is not only the static spatial location information, but also the direction, velocity, trail information. User locational context will support the mathematical and the human-related concepts of space.

The first thought of mobile map generalization considering user locational context, see Figure 1. With different distance increment away from the location of user, space hierarchy in different level, different direction of user movement, map generalisation should consider these altering. The user velocity on different segment of road will also influence map generalization, see Figure 2.

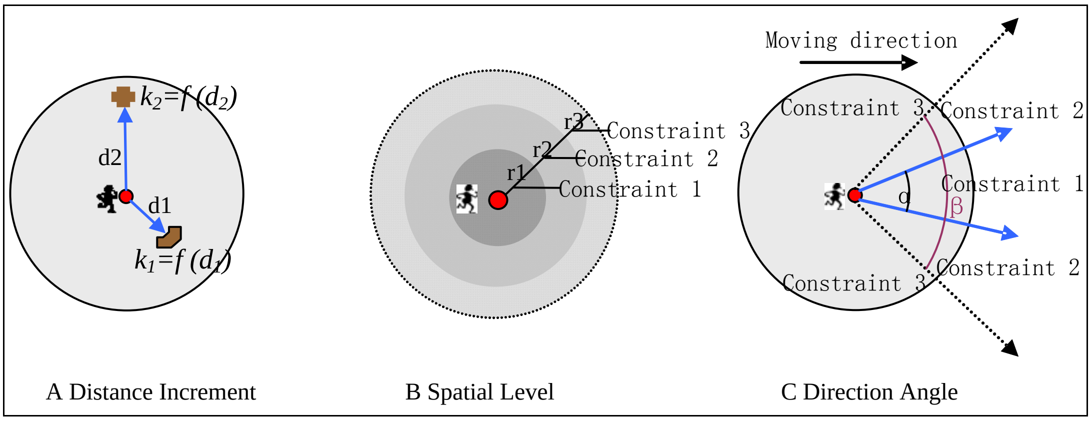


Fig 1 Design idea of mobile map generalization considering user locational context

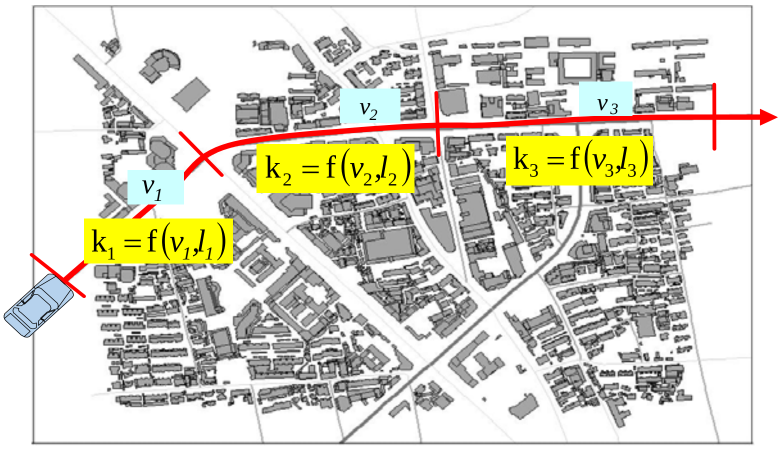


Fig 2 Design idea of mobile map generalization considering user velocity

2. 2 Mobile map generalization framework considering user locational context

Mobile map generalization is a dynamic process and we propose a framework to adapt to the dynamic characteristics of it. The framework mainly consists of four key modules: locational context acquirement, generalisation event triggering engine and dynamic update and adaptive map generalization execution. All the modules will realize user locational context monitor, judge, trigger and perform function. The framework is shown in Fig 3.

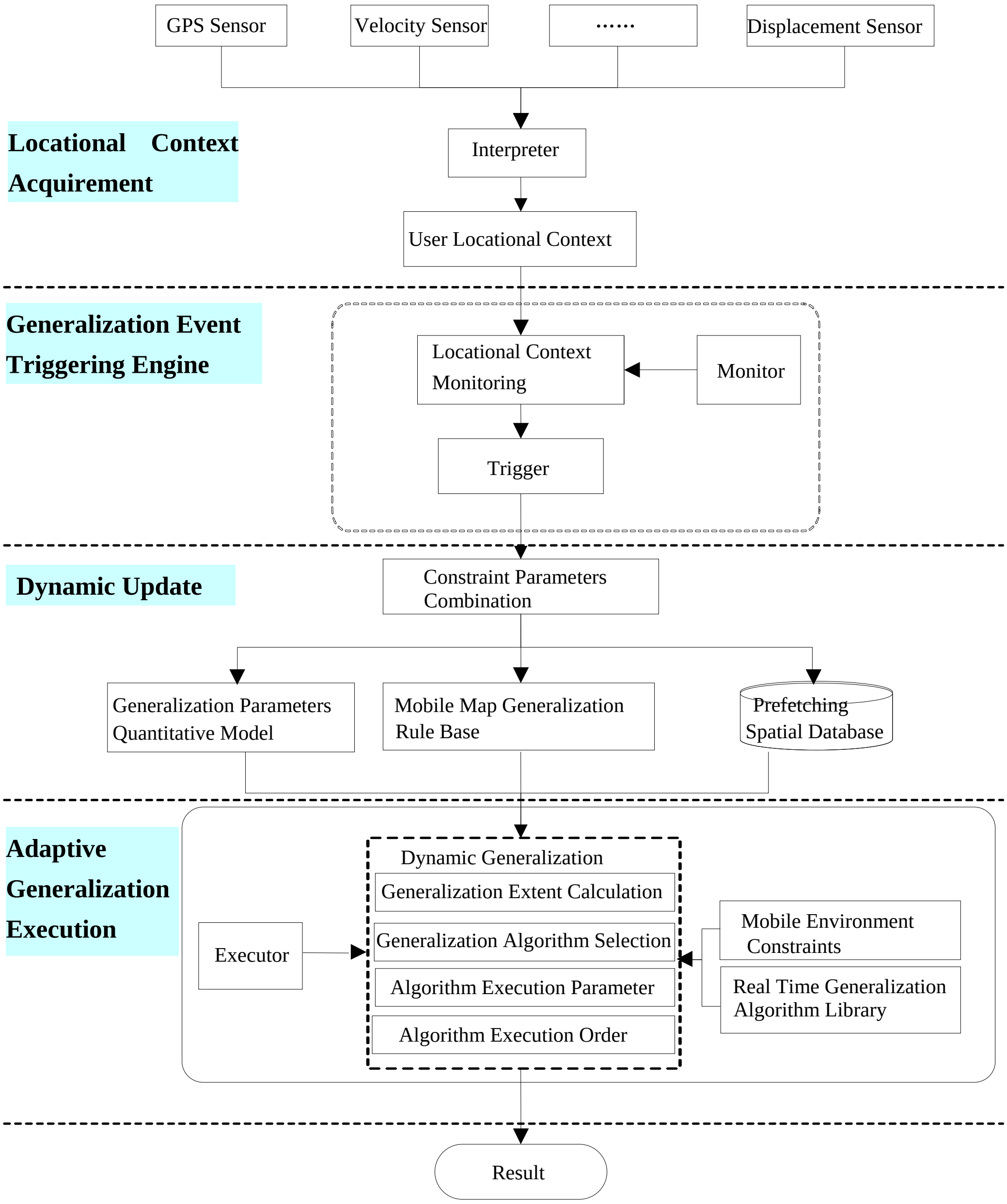


Fig 3 The framework of mobile map generalization considering locational context

3. Relevance between user velocity and generalization constraints

A first generalisation process model on the basis of constraints was developed by Ruas and Plazanet (1996). They proposed the usage of formalised constraints for conflict identification, operator selection and validation of the applied generalisation transformations. Dirk Burghardt(2007) analyzed the usage of cartographic constraints in automated generalization in EuroSDR project . He concluded that there are two methods, constrained-based approaches and condition-action modeling. This study is mainly about condition-action modeling and how user velocity affect the mobile map generalisation. The procedure of our approach is:

- Analyzing which aspect of map generalization the user velocity will affect
- Building the relationship of velocity and mobile map scale
- Analyzing the influence of scale to the selection of generalization operators
- Analyzing the influence of scale to the selection of parameter of generalization algorithms

3.1 Relationship between speed, visual field and attention distance

User velocity as an important context in mobile environment influences the cognition of user. 95% of the visual information is dynamic when user is driving. Ba б y MapkoBa (1990) concluded that the field of vision will become narrow while the velocity is faster. Figure 4 shows the changing situation of visual field in different velocity.

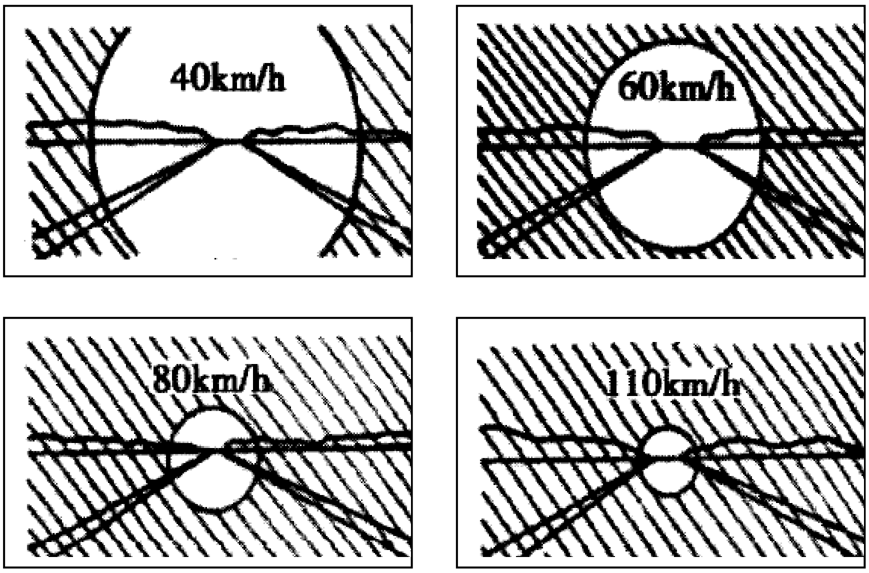


Fig 4 Different visual fields at different velocity

At one moment, the focus of user attention named as fixation, the distance between fixation and the current position of the car called the attention distance. Users in the driving course will focus on the road in front of the car and the higher the speed is, the driver will be more focused attention, so the more difficult the driver transfers his attention. With the velocity increase, narrowing the scope of the user's perspective, the user's gaze also moved forward along farther away from the attention. Pan (2004) concluded the relationship between velocity, visual field and attention distance, it is shown in Table 1. As we can see from the table, with the increased velocity, smaller visual field is, farther the attention distance.

Table 1 Relationship between velocity, visual field and attention distance

Velocity（km/h）	40	60	80	100	120
Visual field（°）	100	86	60	40	22
Attention distance（m）	180	335	377	564	710

The visual fields get narrower with higher speed (as indicated in Fig 3) is especially interesting in generalisation of 3D models. Now some navigation system such as TomTom can offer different scale of map according to the velocity of user. But the different scale map are provided by multi scale database while the velocity changing.

3.2 Relationship between user velocity and the scale of mobile map

Usually in the mobile map applications, any given view, the mapping scope are controlled by the scale. What is the drive of the scale chosen? Scale and zoom function will challenge the cognition of user, but until now few research has been done in this area. The factors related to the decision of map scale and scope is map task context, the user's preferences and interactivity, temporal and spatial context, such as user movement velocity. We observed several navigation systems and found that these software have automatic scaling features. The zoom level is controlled by velocity, types of road, intersection, path length. In general, at high velocity with small-scale or reduced view, but the map is enlarged when user moving closer to the decision point.

As shown in figure 5, Chalmers（2001）intuitively indicate the relationship between movement velocity and map scale using the effectiveness curve. As shown in figure 6, Zhang H.(2005) pointed out that the velocity is also an important factor affected mobile users to use spatial information and revised the map scale effectiveness curve of Chalmers. We revised the map scale effectiveness curve as shown in figure 7.

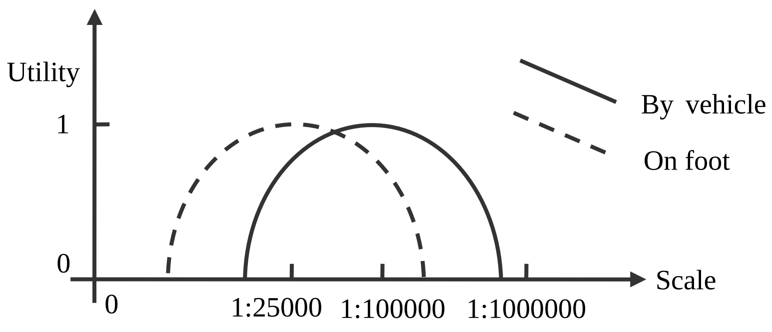


Fig 5 Utility Function for scale（Chalmers，2001）

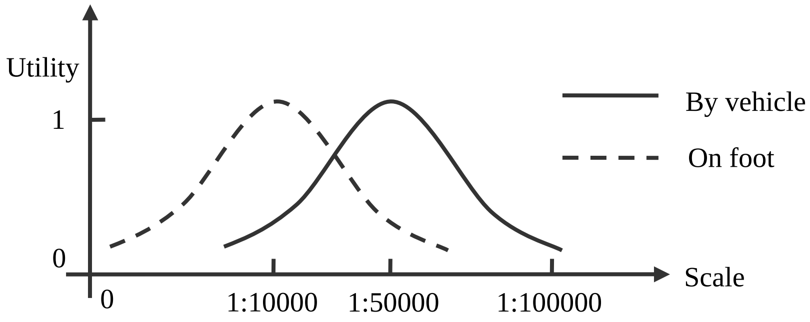


Fig 6　Utility curve of different scales（Zhang H.2005）

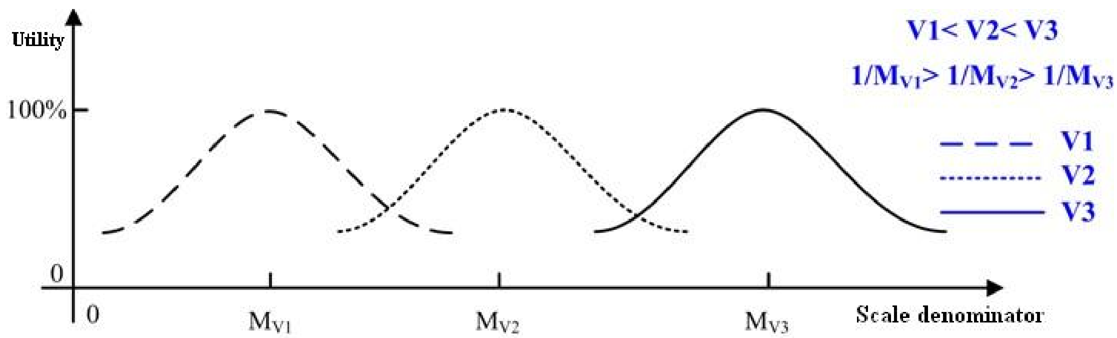


Fig 7　Utility curve of mobile map scales at different velocity

Dillemuth, etc. (2007) in the study of map scale and scope selection in mobile navigation system, in order to transfer the map scale from distance dimension to time dimension, he proposed "Time -to-edge "measurement method. This method refers to converting the display scale of mobile map into the minimum required time from the center of the map to the edge of map with a particular speed. With this method, we can transfer the relationship between velocity and scale into the relationship between the time and velocity. We concluded that velocity, time-to-edge, scale, usability are related each other and selecting a suitable time-to-edge is helpful to improve the usability of mobile map.

3.3　The influence of scale to the selection of generalization operators

There are many generalization operators and algorithms but so far only isolated components performing separate generalization tasks have been available. Burghardt (2005) stated that much progress has been made in the field of web based cartography through standards developed by the Open Geospatial Consortium(OGC).While automated access and presentation of cartographic data are defined, services for automated generalization are not yet standardized. There are several advantages to using generalization services for on-demand map production. They built a frame work for the usage of supporting services, generalization services and process services. Foerster(2006) showed his approach towards a web processing service for generalization based on OGC standards.

Cecconi (2003) studied map generalisation for on-demand mapping, gave the applications of road generalization operators in different scale, as shown in Figure 8. It shows the relationship between road network complexity and map scale, Figure8 shows three scales.

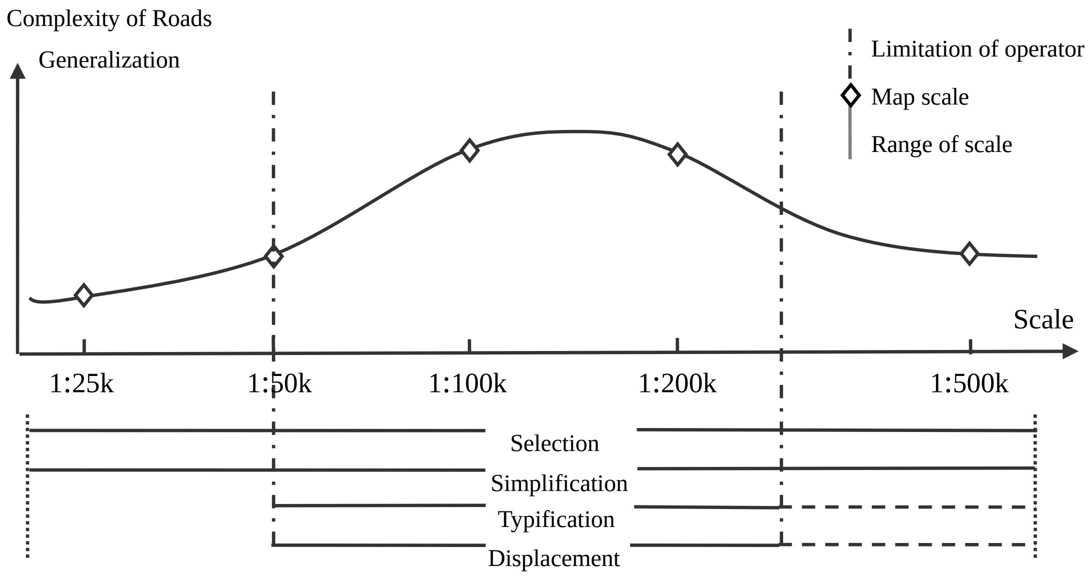


Fig 8 Relationship between road network complexity and the application range of generalization operators in different map scale (Cecconi，2003)

3.4 Relationship between map scale and the parameter of generalization algorithms

There are many algorithms for map generalization and every algorithm has its own parameter. The parameter could be adjusted in a limitation. The selection of parameter is related with the map usage, map scale and the characteristic of map region. We gathered some road generalization algorithms and analyzed the parameter of them, see table 2.

Table 2 Road generalisation algorithms and the parameter

Operator	**Algorithms**	**Parameter**
Selection	According to the level of road	Level of road、attribute
Simplification	N^{th} point	Number of vertex
	Douglas-Peucker	Perpendicular distance
	Lang	Nmax，Dmax
	Perpendicular distance	Perpendicular distance
	Li-Openshaw	svo
	“embrace delete”simplification based on circle	Filter circle radius
	Progressive method	Square
	Visvalingam-Williamson	Square

4. Road generalization algorithm implementation considering the user velocity

The paper discusses the highways, expressways, trunk roads, sub-arterial roads and slip roads and the average speed of five types of road, then carry out the study of road generalization considering user velosity. The experimental area select a piece of Nanjing, including several types of road , experimental area diagram shown in Figure 9.

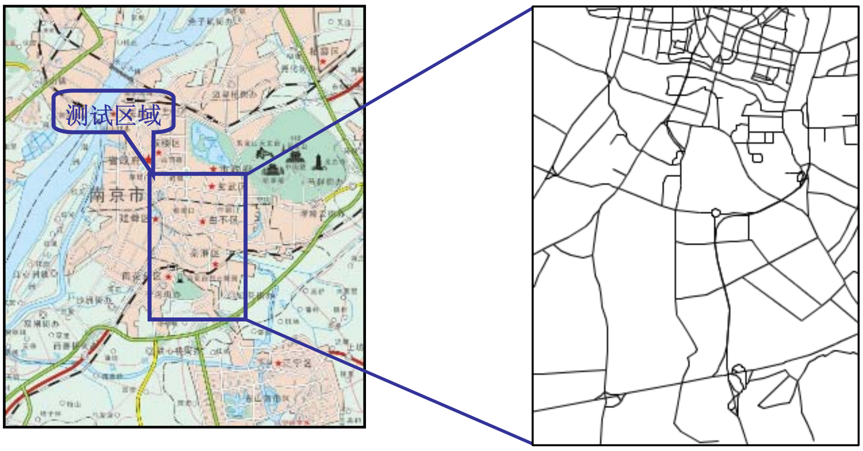


Fig.9 Test area of Nanjing

We implemented selection algorithm according to the level of road and Douglas-Peucker simplification algorithm according to the average velocity of road. The procedure is listed below.

1. We investigated the typology of Chinese road and get the average speed of the road of testing area, see table 3.

Table 3 Average speed of the road of testing area

Type of road	High way	expressways	trunk roads	sub-arterial roads	slip roads
Speed(km/h)	100	80	60	40	30

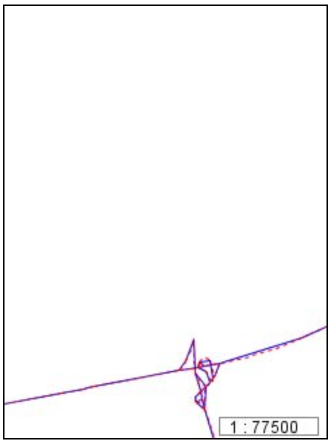
2. We calculate the scale of the map according to the "Time-to-Edge" rule considering the velocity, see table 4.

Table 4 Calculate the map scale according to the "Time-to-Edge" rule

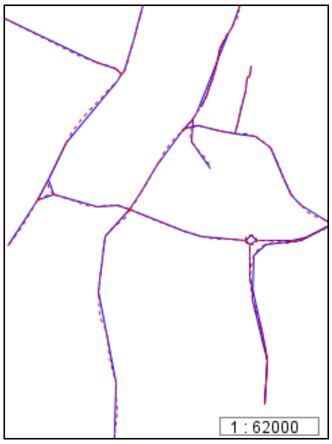
Speed(km/h) / Time (min)	100	80	60	40	30
1	1:77500	1:62000	1:46500	1:31000	1:23300
2	1:155000	1:124000	1:93000	1:62000	1:46500
3	1:233000	1:186000	1:140000	1:93000	1:70000
4	1:310000	1:248000	1:186000	1:124000	1:93000

We get different scale with different velocity according to the “Time-to-Edge” rule, but the suitable value of “Time-to-Edge” should do a lot of cognition experiment. We select 1 minute as the “Time-to-Edge” and calculate the map scale considering different velocity.

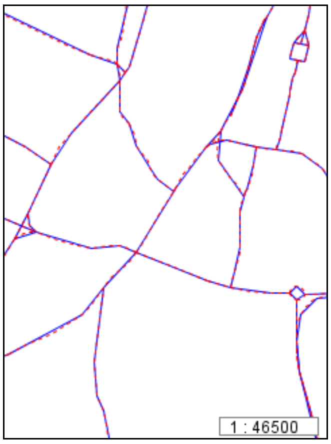
3. Implementing the selection and simplification algorithm considering the average speed of the road. The result see Fig.10.



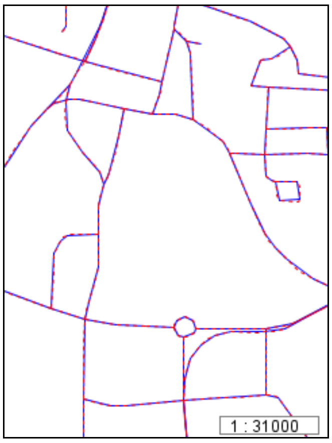
（a）Velocity is100 km/h



（b）Velocity is 80 km/h



（c）Velocity is 60 km/h



（d）Velocity is 40 km/h

（e）Velocity is 30 km/h

Fig. 1 Road generalization considering the velocity

5. Conclusion

We indicated that mobile map generalization has its own characteristics, it can be concluded as partial, dynamic and on-demand of user. Due to the mobility of user, the locational context is the most important context.

Based on analyzing the impact of velocity on the choice of mobile map scale and the influence of scale on the selection of generalization operators, we concluded that velocity, time-to-edge, scale, usability are related each other and selecting a suitable time-to-edge is helpful to improve the usability of mobile map.

Based on the relations of velocity and generalization algorithm of road map in mobile environment and the sets of real-time road generalization algorithms, we implemented the road generalization operation considering user velocity by controlling the selection of algorithms and the parameter of generalization algorithms.

This study did not get deeply with the problem of getting the suitable value of “Time-to-Edge”. The relationship between the scale, generalization operator and parameter is not very clear now. This study would provide reference for further research of the impact of other mobile context on mobile map generalization.

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