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DESIGN OF DYNAMIC MAPS FOR LAND VEHICLE NAVIGATION

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ABSTRACT:

A main component of an Intelligent Transport System (ITS) is the navigation system to be used in the 'intelligent' car. In fact, driving a vehicle is a complex task as the driver has to control the vehicle as well as make decisions about getting to his destination. Too much information on the map (a complex map) would confuse the driver, while too little information would not be enough for the user to compare with the actual environment. Likewise, sufficient information poorly presented would also result in confusion. This paper reports on a study of the optimal design of dynamic maps for land vehicle navigation through an investigation of different designs with different levels of information contents and visual effects using various dynamic variables. Different colour was assigned to the road and building names according to the position of the vehicle, and blinking symbols were used to indicate direction restrictions. Also, a set of maps with different complexity was designed such that the users would be provided with different levels of contents and representation by zooming in and out. The effectiveness of the design was investigated in the map evaluation process.

1. INTRODUCTION

As urban traffic become more and more dense, transportation networks become more and more complex. To deal with this, navigation system emerged. It is believed that the use of navigation systems will become widespread because it can provide useful information on driver's current position, shortest path to destination, and traffic congestion. In this way, time and energy can be saved, and driver stress reduced and environment effect minimised.

Vehicle navigation is a complex task. The driver has to perceive data from many different sources and therefore is in a hazardous and divided attention environment. One can see that a crucial part of the navigation system is the map component as it is responsible for information transmission to the user. The effectiveness of the information transmission from the map to the user is an indispensable measure of the success of the system since it is assumed that safe viewing times of the map are less than two seconds during driving (Sena, 1997). If the transmission of cartographic information is not effective, the driver may have to refer to the map several times to get the information he/she wants. In an even worse case, the driver may keep on viewing the map until he/she gets the desired information, which results in losing contact with the road and may cause a traffic accident. Thus, the design of the map to be used in navigation should be investigated for its effectiveness for information transfer.

Indeed, too much information on the map (a complex map) would confuse the driver, while too little information would not be enough for the user to compare with the actual environment. Likewise, sufficient information poorly presented would also result in confusion. This study aims at optimum design of dynamic and multi-scale maps for land vehicle navigation.

2. REQUIREMENTS OF DYNAMIC MAPS FOR NAVIGATION SYSTEMS

2.1 Implication of Dynamic Maps in This Context

Maps are constructed from visual variables which could be static or dynamic. Primary static visual variables include shape, size, orientation and color, while dynamic visual variables include duration, rate of change and order (DiBiase et al, 1992). According to DiBiase et al (1992), static maps are constructed from static visual variables within two or three spatial dimensions. Time is required to perceive static maps but their forms are essentially atemporal. Unlike static maps, dynamic maps are constructed from static and dynamic visual variables within two or three spatial dimensions and the temporal dimension. Time is intrinsic to the form of dynamic data displays.

There are three modes of cartographic expressions in dynamic displays, i.e. animation, sonification and interaction (DiBiase et al, 1992). They are applicable in vehicle navigation display. In this study, animation and interaction were considered. Animation is the illustration of motion created from a sequence of still images. When a vehicle navigates, its position on the map changes and therefore animation is involved. Animation is also involved in blinking symbols that may be contained in the map. Sonification is the representation of data with sound, and voice guidance is used to accompany the map display in some navigation systems. However, sonification was not considered in this study since this project only investigates visual output. Interaction is the empowerment of the viewer to modify a data display. For example, the user can select the scale to be displayed by zooming in or out.

2.2 Requirements of Digital Maps for Navigation Systems

Map displays were viewed as distractions to the drivers. It was believed that they would take away the drivers' attention for too long a period of time, and instructions should be done by voice output. Some of the countries even stated that map display

represented a safety hazard and tried to forbid the use of them while the vehicle is navigating. However, one cannot deny that map displays do play an important role in navigation systems and systems solely with voice output for instruction may not be sufficient. One of the reasons is that voice guidance is not suitable for communication spatial information such as a complex intersection configuration at a turning point. In contrast, a visual display is suitable for the expression of graphic information like detailed and complex configuration. This poses two specific requirements for navigational maps as follows:

a) It is a very effective graphics. The driver could obtain necessary information with a few seconds;
b) There are sufficient geographical environment depicted so that the driver could recognise the current location of the vehicle;

3. DESIGN CONSIDERATIONS OF DYNAMIC MAPS FOR VEHICLE NAVIGATION

In order to meet these two basic requirements. A number of factors need to be considered in the design process

3.1 Consideration of Heading Directions

Other than the requirements stated above, another important concern in the design of navigation maps is map orientation and two main kinds of map orientation can be classified. One is North-up form which always keeps the North of the map up, and the other is heading-up form in which the map is always rotated to keep the direction of movement of the vehicle in upward form. Mashimo et al did an experiment to investigate driver's characteristics for North-up and heading-up maps of In-Vehicle Navigation System (IVNS). Two conclusions were drawn after the experiments (Mashimo et al, 1993):

a) The display form should be adapted to the driver's characteristics of the spatial orientation.
b) When using heading-up type display, the rotating angle of the map needs a special care, and results indicated heading-up type display which rotates at 45 degrees had best performance.

Several advantages and disadvantages of the two display forms are also pointed out in the investigations, in which some are listed in the Table 1.

	Advantages	Disadvantages
North-up display form	Easy to decide the route.	Difficult to recognise the direction of movement.
	Easy to recognise the destination.	Difficult to adapt the front view.
Heading-up display form	Easy to adapt to the front view.	Difficult to recognise the destination.
	Easy to judge turning right or left.	Difficult to recognize that turnings have completed at intersections.

Table 1. North-up vs heading-up display forms

A recent research by Darken and Cevik (Darken and Cevik, 1999) also investigated the effects of map orientations. They carried out the test with respect to egocentric reference frame (ERF) and world reference frame (WRF). Results showed that search tasks related to ERF are best served by heading-up map orientation, while search tasks related to WRF are best served by North-up map orientation.

Applying those results in vehicle navigation, one may say that a North-up map orientation would be good in pre-planning stage (i.e. route finding stage by the system) since it would be easier for the user to recognize the destination and to have some idea about the route to be taken. On the other hand, a heading-up map orientation should be used once the user starts to navigate since it would be easier for the user to adapt to the front view as well as to judge the direction to go.

3.2 Consideration of Map Complexity and Map Scale

Map complexity may have an adverse effect on map effectiveness and at certain levels impede map communication. Too much information on the map (a complex map) would confuse the driver, while too little information would not be enough for the user to compare with the actual environment. Therefore, a multi-scale concept is used in this study.

The maps used in this study were derived from the digital map series of the Land Information Centre (LIC) of the Government of the Hong Kong Special Administrative Region, China. They were generalized to three scale levels (1:2500, 1:5000 and 1:10000) according to the road classification systems from the Transport Department so that the users would be provided with different levels of contents and representation by zooming in and out. The working scale for this study was 1:5000 (Figure 1), where the maps with scale of 1:2500 (Figure 2) and 1:10000 (Figure 3) could provide a zoom in and zoom out effect respectively.
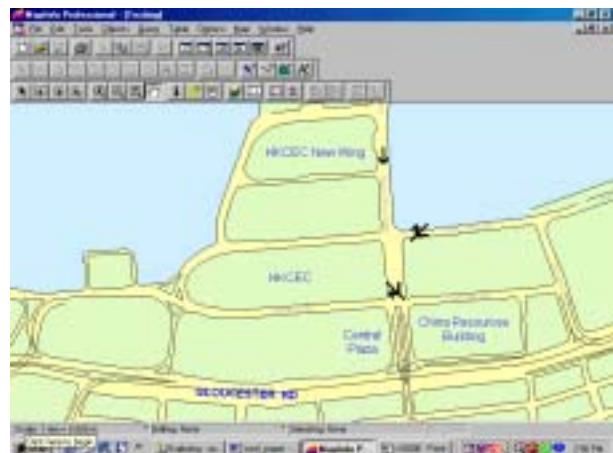

Figure 1. Map with scale level 1:5000

3.3 Consideration of Visual Variable and Dynamic Variables

Other than the information to be put on the map, the design and arrangement of the symbols as well as their arrangements are also critical factors to be considered.

To simulate the use of an in-vehicle positioning system, the system reads the vehicle's position from a coordinate file and

Figure 2. Map in scale level 1:2500
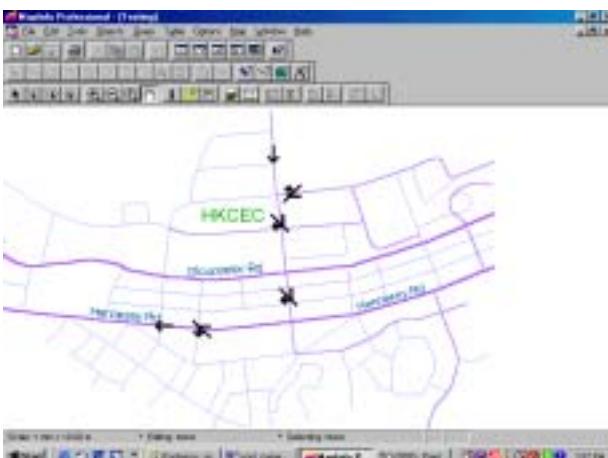
Figure 3. Map with scale level 1:10000

displayed the car position on the map. Small and large buffer zones were created around the car position. The smaller buffer zone was used to select features in the immediate neighbourhood, e.g. the road that the vehicle is navigating in together with the road name. Those selected features would then be assigned different attributes to provide a dynamic highlighted effect, e.g. increase in size, in thickness, contrasting colour and flashing effect. In Figure 4, the red dotted circle indicates the small buffer zone created by the car. The road name "Harbour Rd" fell in the small buffer zone and thus was enlarged and highlighted with a red colour compared with the original road name circled in blue. Also, the road segments which fell in the small buffer zone was coloured in blue. The larger buffer zone was used to highlight the roads in the central part of the displayed area around the vehicle for easier perception for the users (Figure 5).

The program also provided two modes of navigation: (i) navigation with planned route and (ii) navigation without planned route. For navigation with planned route, different parts of the route were highlighted in different colour according to the position of the vehicle (Figure 6). In the figure, the part of route that the vehicle has already navigated was changed into green, the part that the vehicle is navigating in was changed into blue and the part that the vehicle is going to navigates remains with the original pink colour. An example of using perspective

symbol for landmark was also shown in this figure (circled in red). The map provided flexibility to the users to customise their use by activating different layers such as car park and restaurants locations.
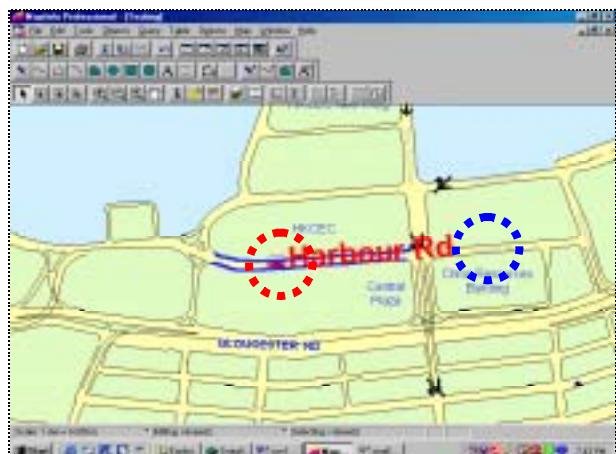
Figure 4. Feature highlighted by small buffer zone
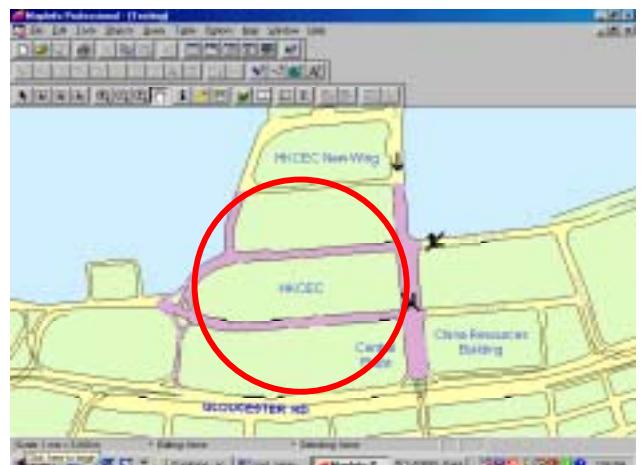
Figure 5. Road segments highlighted by large buffer zone (circled in red)
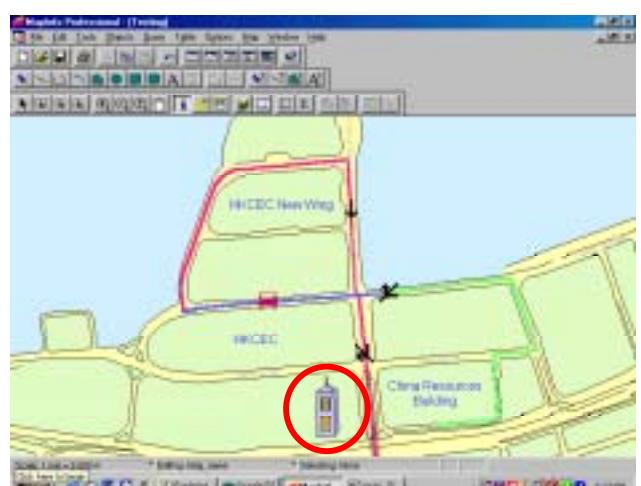
Figure 6. Mode of navigation with planned route and use of perspective symbols

Different type of highlights have been tried. Examples are: road segments were highlighted by changing the colour (Figure 7); building names and road names were highlighted by changing the colour and increasing the font size (Figures 8-9); and direction restriction symbols were highlighted by increasing in size plus flashing effect (Figure 10). Different prominence of map contents was presented. Perspective symbols were designed and direction restriction symbols were designed to replicate the road signs developed by the local Transport Department. Both of them gained appreciation from users.
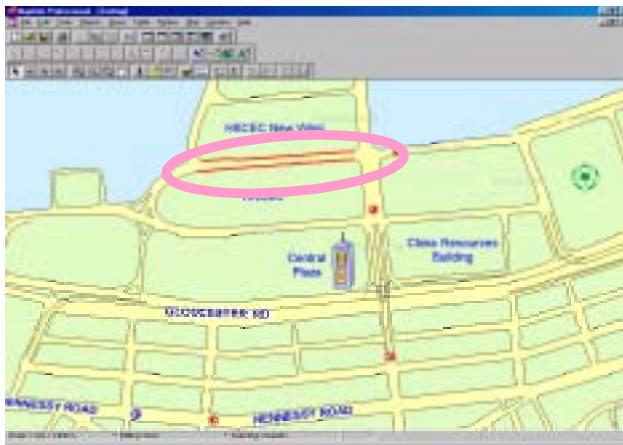

Figure 7. Highlight by changing the colour of graphic symbol

Figure 8. Highlight by enlargement of text symbol

3.4 Consideration of Viewpoint

Maps depict an orthogonal view of the terrain objects. However, perspective view would be more perceivable in reality. In this study, perspective symbols have been used. However, it would be also a good idea to use maps in perspective (Figure 11).

4. EXPERIMENTAL EVALUATION

The objective of this study was to investigate how the information for vehicle navigation should be presented to be most effective to achieve optimal performance on navigation tasks, and whether use and preference were different for different subgroups of map users. Subjects were chosen who

Figure 9. Highlight by changing the colour of text symbol

Figure 10. Highlight by enlargement of graphic symbol

fulfilled the dichotomous attributes of novice/expert and male/female with equal proportions. In total, results from 60 subjects were analysed.

Evaluation test reveals that the use of a small buffer zone to highlight features in the close neighbourhood of the vehicle was found to be helpful in map perception, both for scale levels 1:2500 and 1:5000, and no matter when the vehicle navigates with or without a planned route. The use of a large buffer zone to highlight the roads in the central part of the displayed area around the vehicle also showed helpfulness in perceiving the map in the working scale 1:5000, for both of the modes of navigation with and without a planned route. With these results, the next step was to evaluate how to change the features' attributes within the buffer zones in scale level 1:2500 and 1:5000.

It was found that using a perspective icon was helpful. In the planned route mode of navigation, changing the colour of the part of the route that the vehicle going to navigate and already navigated was effective in helping the users to perceive the map. The highlighting effect produced by an increase in feature's size was very helpful for direction restriction symbols, quite helpful for building and road names, and not helpful for road segments. The highlighting effect produced by changing the colour was very helpful for all of the above four features. The flashing

effect was very helpful to be applied for direction restriction symbol, quite helpful for both building name and road name, and not helpful for road segments. However, opinions from subjects claimed that too many flashing effects on the map would be distracting and irritating. Therefore, it would only be applied to the most effective one, i.e. the direction restriction symbol.
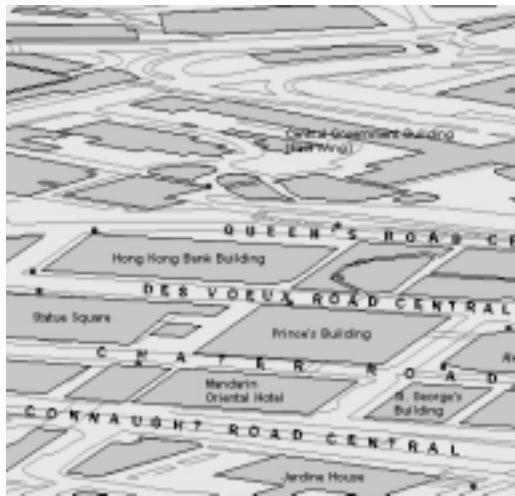

Figure 11. Perspective views of maps (Lee, 2001).

5. CONCLUSIONS

In this study, dynamic maps with multi-scale representation have been designed for land vehicle navigation. In the design, various visual variable and dynamic variables are considered to produce good visual effect. Experimental testing results confirmed its effectiveness of these designs for such a purpose. It is hoped that the results from this research will be beneficial to future studies involved in this area.

However, there are some areas in this study that would be modified and improved. The orientation of the map used in this study was in North-up form. It would be good in pre-planning stage since it would be easier for the user to recognise the destination and to have some idea about the route to be taken. On the other hand, a heading-up map orientation should be used once the user starts to navigate since it would be easier for the user to adapt to the front view as well as to judge the direction to go (Mashimo et al, 1993; Petkovic et al, 1997; Darken and Cevik, 1999). A bird's-eye view map could also be considered in vehicle navigation. Usefulness and effectiveness of this design has been reported by Watanabe et al (1998).

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