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DESIGN OF DYNAMIC MULTI-SCALE MAPS
FOR LAND VEHICLE NAVIGATION

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Abstract of thesis entitled ‘Design of Dynamic Multi-Scale Maps for Land Vehicle Navigation’ submitted by Ho Tim Yee, Angelina for the degree of Master of Philosophy at the Hong Kong Polytechnic University in December 2000

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 cartographic design of a navigation map through an investigation of different designs with different content levels. Attention was focused on the use of dynamic variables where features in close proximity of the vehicle would be highlighted such that the prominence of map contents was not a constant in order to lower the map complexity. Users were provided with two modes of navigation, with or without the planned route. A function to calculate the restricted road area according to the time was developed and gained positive comment from users. The effectiveness of the design was investigated by using a map complexity test suggested by MacEachren in 1982. It was concluded that road segments were highlighted by changing the color; building names and road names were highlighted by changing the color and increasing the font size; and direction restriction symbols were highlighted by increasing in size plus flashing effect. Different prominences of map contents were 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 appreciations from users. 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 results were then confirmed by a viewing time record. Finally the design of the map was investigated by a map evaluation process.
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CHAPTER 1
INTRODUCTION

1.1 Vehicle Navigation in Intelligent Transportation System (ITS)

As urban traffic becomes more and more dense, transportation network becomes more and more complex. The congestion of road traffic has become a difficult problem for both the economy of the country and the daily lives of individual citizens. To deal with this, Intelligent Transport System (ITS) was emerged. It is the application of modern telecommunications and information technologies in the transport and traffic fields in order to control traffic flow, charge tolls automatically and send route information to ‘intelligent’ cars. Updated information such as traffic delays, construction, detours, accidents and traffic readjustments in several geographic regions can be sent to ‘intelligent’ vehicles via a radio or TV station in a real-time manner. Therefore, drivers could know where they are, which routes they are taking, alternative routes and the statistic of the traffic for each route and other information related to the routes in order to make the best decision about their journey, resulting in reduction of traffic jams and better distribution of the overall traffic. In fact, transport is key to social and economic life and ITS should increasingly be used as it has many advantages. Examples are improved efficiency of road use, convenience to general public and reduced traffic congestion.

Main component of ITS is the vehicle navigation system. It assists drivers in dynamic route planning by providing incremental instructions. Drivers were guided through geographic space and as a result time and fuel were saved. In traditional vehicle driving, both planning and decision making are based on the driver’s mental model of his/her environment, i.e. the cognitive map. With the use of vehicle navigation system, the planning and decision making were supported by additional source of data, i.e. the map display and the voice output for direction instruction.
Amount of time for the driver to update his/her cognitive map was reduced, resulting in increase in time for decision making. It is believed that navigation system will become widespread because it can provide useful information on driver’s current position, minimum path to destination, and traffic congestion. In this way, time and energy can be saved, and stress being reduced.

This project deals with a specific topic in ITS --- navigation. As one of the main component of a navigation system is the map display, this project aims at designing an effective dynamic multi-scale map for land vehicle navigation.

1.2 Significance of Study

One of the main components of ITS is the navigation system. Concerning the information given by the systems, it could be given through various modalities: auditive (by voice output), visual (by map display) or both. Considerable theoretical and practical work on systems to compute paths and generate verbal directions has been conducted (Elliott and Lesk, 1982; Mark, 1985, 1987; Davis, 1986; Ma, 1987; Davis and Schmandt, 1989; Kishi and Sugiura, 1998). Mark and McGranaghan (1986) and Streeter and Vitello (1986) had argued that verbal advice might be more effective than in-vehicle map displays. However, it is estimated that over 90% of the information input to the driver is visual (Hills, 1980). It does not require speaking a specific language and this universal understanding is an advantage in the world of today. Furthermore, voice guidance is not suitable for communication 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. 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. Indeed, voice guidance and visual display can be complementing each other.
Visual output of navigational information could be given through the use of paper maps or by electronic displays. Wierwille et al. (1989) investigated the effects of a paper map and an electronic map-based navigator on driver behaviors, and concluded that the electronic navigator could be used effectively by the driver with no differences in lane exceedences and brake accentuations. It was confirmed by Schraagen (1993) in a later study that the use of in-vehicle information system was more efficient than the use of paper map.

Traditionally, map readers were provided with a single "best" map. With the advance in computer technology, cartography was provided with a more flexible environment for viewing maps. Representations of spatial information can be constructed by electronic media and methods, creating interactivity and dynamic illustrations. Grossman (1990) lists potential applications of applications of dynamic maps in geographic-information-system-based environmental assessments, but he only considered chronologically ordered sequences of static maps. Typical dynamic visualization was done by using time-lapse animations created from time series data or from sets of remotely sensed images (e.g. Tobler, 1970; Monmonier, 1990) and a wide variety of techniques has been developed since the mid-1970s for animating spatial data in this way (Campbell and Egbert, 1990). However, not much study was done in the dynamic visualization by geographic position simulations. One common application was the dynamic display for vehicle navigation according to the vehicle’s geographic position. However, this field has not been explored well and the requirements for an effective cartographic presentation for navigation still remain vague. The contents to be put in the navigation map as well as their presentations have not been fully investigated. The recommendations in this case are to display information as relevant as possible to the navigational purposes (Schraagen, 1990) and to evaluate how information should be presented effectively.

Ordinary map display contains too many information not directly relevant for navigational purposes when compared to guidance information (Schraagen, 1993). Labiale (1989) compared map displays of two levels of complexity and found that recall performance was better with the simpler maps. Differences were more
pronounced in the condition in which drivers had to read the map while driving. However, a simple map may not contain sufficient information needed by the driver. Therefore, a map with consistent complexity (either high or low) may not be ideal for navigation. Although there had been much research which assessed vehicle navigation system interfaces (e.g. Wierwille et al, 1989; Lamellet, 1994; Pauzie, 1994; Burnett and Joyner, 1997; Petkovic et al, 1997; Schell, 1997; Burnett, 2000), all of them were designed with consistent map complexity. This project investigates the design of a dynamic multi-scale map for land vehicle navigation, in which different scale levels were designed with different complexities. Turn-by-turn instructions with increased prominences would be given according to the vehicle’s position. It was stated that the use of turn-by-turn systems which gives instructions according to the vehicle’s position leads to less navigational errors and shorter journey times, reduced mental demands and increased confidence in navigating (Streeter et al, 1985; Walker et al, 1991; Burnett, 2000).

In fact, driving is a complex task in the sense that the driver has to perceive data from many different sources and is in a hazardous and divided attention environment. The driver has to constantly observe the environment to catch cues (e.g. road signs, street names, buildings and landmarks) and at the same time to make decision to get to the destination. If the driver is driving with a navigation system, then the driver could save some time for decision making since the route is planned by the system and the system would guide the driver through the route. However, the driver still has to consistently compare the perceived cues with the cues given by the navigation system to make sure that he/she is driving in the right way. Therefore, the effectiveness of the map is very important since it is assumed that safe viewing times of the map are less than two seconds during driving (Sena, 1997). If the effectiveness was low, the driver may have to refer to the map for several times to get the information he/she wants. In an even worse case, the driver may even keep on viewing the map until he/she gets the desired information, which results in losing contact with the road and may causes accident.
As a result, good design of the effective navigation map is indispensable to the
successfulness of a navigation system. Too much information on the map (a complex
map) would confuse the driver, while too less information would not be enough for
the user to compare with the actual environment. According to MacEachren
(MacEachren, 1982), map complexity may have an adverse effect on map
effectiveness and at certain levels impede map communication. However, it is
unlikely that all increases in map complexity will result in a corresponding decrease
in effectiveness. Therefore, the complexity-effectiveness relationship should be
examined carefully to get the effective result. Other than the information to be put on
the map, the design of the symbols as well as their arrangements are also critical
factors to be considered.

Although underlying principles of cartographic design for conventional maps
have been achieved with high significance, design principles for navigation map have
not been developed well. One can see that navigation map would be different from
the conventional topographic one in the sense that it is dynamic while the latter is
static. Conventional topographic map contains detailed features which could be
considered as noise for vehicle navigation. Moreover, the prominences of contents
were fixed in the stage of map design. Dynamic maps offer the advantage that
features' prominences could be varied from time to time. In the application of vehicle
navigation, they could be changed according to the vehicle's position such that those
feature in intimate neighbourhood of the vehicle could be highlighted. Other features
which were considered to be less important to the driver could be assigned with less
prominences such that attention would not be diverged. According to Shepherd
(1995), graphic appearance of symbols can be varied during display time to represent
values of attribute variables. The most popular examples are symbol blinking and
flashing. MacEachren also suggested to use blurred symbols to indicate features
whose attributes were known only within a broad value range (MacEachren, 1992).
Sizes and hue/value/brightness of features might be adjusted according to their
importance. Those concepts would be applied in this study. Prominence of features
will be changed in a dynamic way according to the vehicle's geographic location.
New concepts and design could be developed exclusively for navigation maps. One
has to fully investigate how the information should be presented to be most effective
to achieve effective performance on navigation tasks. Karl (1992) suggested that new forms of animated maps may be revealed through experimentation and therefore it was applied in this study. Attention would be focused on the expression grade of map contents by the use of perceived map complexity test.

1.3 Objectives of This Study

This project aims to investigate the effective design of multi-scale maps for land vehicle navigation. Attention was focused on the decision of effective expression grade of map contents which is done by the perceived map complexity test. In another words, it is to design effective maps to aid land navigation, which is achieved by:

- Effective use of visual variables and dynamic variables.
- Assigning different prominences to contents according to the vehicle position.
- Design of effective symbols for navigation maps.
- Investigation of different designs to obtain an effective one.

1.4 Organization of This Thesis

Following this introductory chapter, a review for navigation as well as the maps to be used in it would firstly be provided in Chapter Two. Then Chapter Three describes the factors to be considered in the design of dynamic maps for vehicle navigation, followed by a discussion of how to put those factors into application in Chapter Four. Chapter Five presents the implementation of this study, including details about the source data, how the data was modified and put into the working platform. The experimental design together with the findings and analysis are
explained in Chapter Six. Finally, Chapter Seven brings the thesis to a conclusion with a summary and discussion of the limitations and recommendation for future research.
CHAPTER 2

MAPS IN VEHICLE NAVIGATION SYSTEM

2.1 Vehicle Navigation System

The word ‘navigation’ means different things to different people. For example, it refers to the long distance migrations of animals such as birds and fish to most zoologists. For most, navigation is the human activity with the aim being to arrive at a predetermined destination and this is used as the meaning in this project. One should note that ‘navigation’ is different from ‘pilotage’. For a person who navigates, usually he/she is familiar with the destination or goal, but not familiar with the route or terrain between this goal and the present location. Navigation and pilotage can be distinguished in the sense that navigation is the method of determining the direction of a familiar goal across unfamiliar terrain whereas pilotage is the method of determining the direction of a familiar goal across familiar terrain.

All vertebrates, including human beings, have some level of navigational ability. Assume a person is in a room and see something on the other side of a room and wish to get to it, he/she can navigate his/her way by looking at the object and walking towards it. However if the thing is in another room where he/she cannot see it, he/she will navigate around the house using familiar objects for guiding. This familiar object is referred to as landmark, which is something special and unique which enables us to tell for certain that we are in one particular place and not in another. A tall or famous building, a lighthouse and a road junction can all be landmarks.

Navigation can be done on foot or in any sort of vehicles such as cars, ships and aircraft. The destination can either be in or out of one’s field of sight. In this
project, we concentrate on "land vehicle navigation", which means navigation by means of car and with destination which is out of sight.

When one wants to navigate to a district which he/she does not know, directions must be needed. The directions can either be given verbally or by drawing a diagram with landmarks and turnings marked on it, and this diagram can be referred to as a map. A map to its simplest sense is just like a picture, which shows in miniature where things are on the ground in relation to each other. Once we can find out our position and the destination on the map, the route can be found out. We can find our direction and follow the route by using a compass or by relating ourselves to some landmarks on the ground with that on the map.

Sometimes navigation can be done without a map. A typical example happens when a child tries to find a place on the street by asking someone passing by. Most probably the answer would be like "walk down straight for twenty paces, turn left and walk ten paces". This method of keeping a constant record of the progress to estimate the position is known as dead reckoning (D.R.). This is the first and most basic way of navigating and was used long before the days of radio and radar.

For land vehicle navigation, the driver will use a street map or a driving guide to find out his/her way for most of the time. Usually before he/she starts the trip, he/she will find out his/her current position and the destination position and then to plan a route. If the route is short, then the driver will be capable to memorize it. On the other hand, if the driver has to go to a distant place, most probably he/she will have to add in intermediate points and break the whole route into shorter ones. Whenever he/she gets to the intermediate point, he/she has to stop the car and then to look at the map again to find the way to another intermediate point. This has to be done repeatedly until the destination is reached.

Obviously, this is inconvenient as it may be difficult to find a place to stop and park the car such that the driver can look at the map to find the way out. Some drivers
may refer to the map during red traffic light or even when driving which may result in accidents. Moreover, in general the start point and the destination are located in different pages of the guidebook. This may be even bothersome if the route is long and intermediate points are involved. Another disadvantage is that it is not so easy to plan the route and the route that we plan may not be the most effective way to get to the destination. One of the reasons is that we may not be familiar with the district and there are so many turn regulations that make the planning a hard job. Furthermore, the traffic condition is not taken into account in the planning. Time to be taken to reach the destination will be longer if we come across with traffic congestion on the way.

Contrasting to the traditional way of navigation, Global Positioning System (GPS) is employed in this area nowadays and has made navigation systems practical for a number of land-vehicle applications. Many GPS-based navigation systems can be found in motor vehicles, farming and mining equipment.

When a GPS receiver (sensor) is mounted on the car and connected to a laptop computer, the location of the car can be accurately determined. The computer continuously collects data from the receiver to compute the car’s location and then conveys this locations to the driver by means of an electronic user interface.

Nevertheless, in general, a land vehicle navigation system cannot position a vehicle continuously solely by using a GPS receiver. This is because the satellite signals that the GPS receiver locks on cannot bend around or pass through solid objects. Any tall building or dense foliage that stands between a GPS receiver and a GPS satellite will block the satellite’s signal. Thus for an urban area with many tall buildings like most of the places in Hong Kong, a GPS receiver may be unable to provides a position fix for long period of time. As a result, other navigation aids have to be used in conjunction with the GPS positioning system to enhance the system performance and thus provide more accurate results. Examples are gyroscope, compass, odometer, inclinometer, accelerometer and D.R. sensor. Among those, D.R. sensors are highly utilized in Hong Kong because they accurately measure changes of the vehicle’s position over a short period of time. They are suitable to be used in
Hong Kong since Hong Kong has many high-rise buildings which would possibly block the GPS signals. When GPS signal cannot be received, D.R. will be applied such that the distance and direction traveled are counted and calculated to estimate the position. Although errors in position estimated by D.R. will accumulate, they are corrected by the GPS position fix once it is available again.

After the determination of the vehicle’s position, it then goes to the presentation of the position to the driver and map databases are frequently used. The map database is not only used for display but also can improve navigation accuracy by applying a map-matching algorithm. Map-matching algorithm is a software algorithm, which combines the sensor data with the map data to produce a position estimate. It is done by following the vehicle’s progress through an on-board digital map and matching the output from the sensor to the closest point on the map. Pattern-matching techniques are involved that tried to correlate the pattern created by several consecutive position fixes to a similar pattern of connected roads in the local road network. When the matched road is found, its information can be used to calibrate the errors from the GPS and the D.R. sensors.

Apart from the graphic output, most navigation systems also provide voice output as verbal instructions. If only graphic output is provided, the driver has to refer to the screen every time he/she comes to a road junction in order to find out the way to turn. This is inconvenient and most importantly, dangerous. Frequently referring to the screen will distract the driver’s attention on the road. The whole idea of the navigation system is summarized in Figure 2.1.
Figure 2.1 Functional schematic of a land-vehicle navigation system.

One can see that there is transmission of update traffic information from the radio/TV station to the user's laptop computer. This part is important in the sense that the dynamic changes that occur in real traffic environment can be taken into account. Information about traffic delays, construction, detours, accidents and traffic readjustments, etc. can be transferred to the users. In the past, this information was broadcasted to drivers via the radios. However, this was not effective enough to detour most of the vehicles. Vehicles will be trapped in the traffic jam, and as more vehicles arrived, more got trapped there. With the new navigation system, on the other hand, traffic information can be broadcasted by a local radio/TV station and update the digital map in the car’s navigation system. This digital map, with the most current traffic information, can give the driver a current availability and traffic volume of the route, which in turn provides a better route planning, reduced traffic jams and better distribution of the overall traffic.
Nowadays, GPS-based land navigation systems are widely employed in many places in the world, including Japan, Taiwan, Europe and the United States. Examples are Zenrin Navisoft by Zenrin Co. Ltd, QuickScout™ (a Traveler Information System™) by Siemens, CARiN™ Navigation System by Philips, SkyMap by Sony and Navigation Genie by Geolnfor Scientek Consultant Inc. As the system is effective and cost-effective, it is believed that the market will continue to expand. One study estimates that the world market for GPS-based in-vehicle navigation systems will be $3 billion by the year 2000 (Figure 2.2). Taking Japan as an example, it is estimated that the sales of vehicles with factory-installed navigation systems will reach 2.5 million by the year of 2000 (French, 1993). Evidences have proved that application of GPS into navigation will continue to grow with the demand.

![Bar Chart](image)

**Figure 2.2** Worldwide market projections of GPS-based in-vehicle navigation systems. (Source: U.S. GPS Industry Council)
2.2 Evaluation of a Local Vehicle Navigation System

Having some idea about the basic functions and requirements of digital map for vehicle navigation, one may want to select a navigation system for evaluation. In this study, a local system was selected because there exists differences between the local road network and the overseas ones. In Hong Kong, the road network is quite complex compared with other countries. Turn regulations and restricted road areas differ in different time zone of the day. Some road signs are not clear, while some are located at the end of the roads which don't provide drivers with enough time to respond. Drivers always got confused with the road restriction system and found difficulties to find detours in the heavy traffic volume. One may say that it calls for the need of navigation systems designed for local use but unfortunately there weren't many in the market. Therefore, a local navigation system named ESNav is selected for evaluation. ESNav is a vehicle navigation system produced by E&S Land Data Management Consultants Ltd. It is the first vehicle navigation system in Hong Kong, and was put into market for the public on 15th May 1999 in the Computer Expo'99.

The system consists of a GPS receiver for positioning (ESLD38) plus a database for guiding navigation (ES Map). ESD38 has a positioning accuracy of 15m and is connected to ES Map. However, the position of the vehicle is only achieved by signals from GPS. None of the map-matching, DGPS nor D.R. technique was employed. As mentioned before, Hong Kong has many high-rise buildings that would possibly block the GPS signals. This may cause a problem if the positioning of vehicle solely depends on the acquisition of GPS signal.

For the ES Map, its map base is a vector one and four scales of display (1:20000, 1:10000, 1:5000 and 1:2500) are available for zooming in and out. Yet, only two smaller scales (1:20000 and 1:10000) are available when the GPS receiver is turn on, i.e. for most of the time only two scales are available.
Details contained in the database include names of roads and places, locations of parking places, petrol stations, convenient shops, restaurants (two chosen), hospitals, MTR stations and most importantly the road network which consists of main roads, minor roads, expressway, light railway, MTR and KCR. Different levels of details will be displayed in the four scales. Nevertheless, the text fonts shown in 1:20000 are quite dense that would be quite difficult to see. Also, the details contained in the system may not be most effective for navigation. Some may be missing and some may be excessive. For example, it seems the inclusion of MTR location might be a surplus since vehicles are navigating on the ground and thus the location of MTR under the ground might not be important. On the other hand, some useful information for driving such as turn regulations and restricted zones are not included in the database.

For GIS functionality, two basic operations can be found in the database, which are searching and buffer zone generations. User can input the name of a road, a place or a estate and the geographic location will be shown. User can also select a place for the system to create a buffer zone of 1km to search for hospital or restaurant within the buffer zone. However, there is no hierarchical grouping of the names of places. User has to scroll down all the list of name to find the desired place, making the search very inconvenient and time consuming. Moreover, the system does not provide path-finding function, which might be considered as the most important function in vehicle navigation. As a result, the user has to plan his/her own route to get to the destination and no direction instruction can be obtained from the system. Furthermore, the display format of the map is North-up instead of heading-up, which is considered to be less effective in updating the user’s cognitive map.

As a whole, it seems that this system still has many shortcomings. Being the first vehicle navigation system to be put into market in Hong Kong, it still has much room for improvements. Luckily, user can download succeeding version from the Internet later on such that updated information can be obtained.
2.3 The Use of Maps in Vehicle Navigation System

The basic type of map used to represent land areas is the referenced map (Kajan et al, 1995). Referenced maps include topographic maps, marine charts and urban plans. They show the specific natural features of the area covered. Among those, topographic maps are most often used as general reference maps since they contain great variety of information. One may say that the most effective way to accomplish location is through the use of maps. However, the maps for vehicle navigation must be different from ordinary topographic map since the complex information that it contains may confuse the driver. Although a paper map could be used to find a location, a digital road map is used to automate this process in many vehicle navigation systems. According to Petkovic et al (1997), the usage of maps in vehicles began approximately ten years ago when Etak, a California-based company, introduced its vehicle navigation system. The development of digital cartography (computer-assisted cartography) can be divided into three stages as indicated by Morrison (Morrison, 1980):

1. The period of the early 1960s when cartographers had a "wait-and-see" attitude;
2. The period of the late 1960s and 1970s when cartographers replicated products which were done manually by a previous technology; and
3. The post 1980s when there was a full implementation of new products.

During the developing stage of navigation systems, map displays were initially viewed as distractions to the drivers and thus were not added in most cases. 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 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. Indeed, voice guidance and visual display can be complementing each other. The voice guidance firstly informs the driver when it is approaching a turning point, and then the driver can confirm the intersection configuration by scanning the visual display. Maps were added to the navigation systems in order to provide the driver with a way to verify that the systems' voice or manoeuvre instructions had been correctly followed. The utility of both outputs is thus enhanced. Demand for map displays to be used together in the systems increased and thus systems developers were gradually forced to add them as a result of market pressure. However, due to the system developers' discomfort with the map paradigm and their lack of cartographic knowledge, relatively crude maps were resulted in majority of these systems.

It is clear that the digital map plays an important role in the vehicle navigation system and therefore its design would be a significant part in the whole system. However, there may be a great difference in the design of paper map and map on screen, in which the former is a static medium of information representation while the latter is a dynamic one. Therefore, the research achievements in digital cartography may not be totally transferred to the application in navigation.

Some basic functions and requirements of the digital map to be applied in vehicle navigation system are suggested by Petkovic and Kajan et al which are summarized as follows (Petkovic et al, 1997):

- The map must show the vehicle's current location in the context of an appropriate geographic environment;
- The map must be constantly updated as the vehicle moves along the road (moving map);
- The map must be adopted to driver's cognitive map;
- The map must allow zoom in and zoom out operation, change the scale and the level of detail;
• The map must serve as background in displaying vehicle's route and the shortest path among two locations;

Advanced requirements may include:

• Detailed list of streets and places' numbers to allow the user to select a destination;

• Accurate representation of the road network with turn regulations, one/two way streets, speed limits.

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):

1. The display form should be adapted to the driver's characteristics of the spatial orientation.

2. 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 2.1.
Table 2.1   Advantages and disadvantages of North-up and heading-up display forms

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>North-up display form</td>
<td>Easy to decide the route.</td>
<td>Difficult to recognize the direction of movement.</td>
</tr>
<tr>
<td></td>
<td>Easy to recognize the destination.</td>
<td>Difficult to adapt the front view.</td>
</tr>
<tr>
<td>Heading-up display form</td>
<td>Easy to adapt to the front view.</td>
<td>Difficult to recognize the destination.</td>
</tr>
<tr>
<td></td>
<td>Easy to judge turning right or left.</td>
<td>Difficult to recognize that turnings have completed at intersections.</td>
</tr>
</tbody>
</table>

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.
Apart from the map orientation, another important concern in map design is the map scale. Map scale is the ratio between a distance on a map and the corresponding distance on the earth. It influences the decision of elements to be put on the map. The larger the map scale, the more contents could be expressed and vice versa. However, applying the term “scale” on screens may be confusing, since the displayed size of objects is related to the size of the screen and could be changed by zooming in and out. Therefore, the term “scale” would be better substituted by “scale level”.

Different scale levels would contain different contents, generalizations and symbolization. Zooming of the maps would correspond to different scale levels; e.g. zooming in would have a display of higher scale level with more details and larger size of objects. These scale levels are indispensable for a well-balanced and readable appearance of map graphics. In most vehicle navigation systems, several scale levels will be available. Usually a map with low scale level will be displayed in the preplanning process of the driver before he/she starts driving. This map can display the user’s current location, the destination location, as well as the route planned by the system to give an overall picture to the user. When the driver started driving, another map with higher scale level will be displayed. Unlike the previous one, this map may contain more detailed information such as instructions for driving direction and street names in order to guide the driver to the destination with the route planned by the system. The system may also allow the user to switch between maps at different scale levels in order to provide flexibility.

As mentioned before, maps to be used in vehicle navigation systems should be divided into two kinds, one for pre-planning stage and the other for navigating stage. Obviously, the scale to be used in them should be different. Small-scale maps should be used for pre-planning stage since the users have to get an overview of the route to be navigated. Large-scale maps may not be suitable since most probably it cannot cover the whole area of the route. On the other hand, maps for navigating stage should be in larger scale. When the driver started the navigation, he/she had to perceive more detailed information from the map, such as turn regulations and
position of landmarks. If those information was contained in a small-scale map, it might be complex for the driver to perceive. A driver would not likely to gaze steadily at a monitor while driving. Instead, those information would be seen at a glance (Watanabe et al, 1998; Kish and Sugiura, 1998). Moreover, the driver might be navigating in a minor road which might not be contained in a small-scale road. Therefore a small-scale map may not be suitable for the working scale in navigation.

Sena (1997) suggested to use a set of maps with scales ranging from 1:10000 to 1:1 million to cover the whole area of Germany, and to provide users with different views of the route. A prototype of vehicle navigation system, called VNav, used scaleable maps which are captured using paper maps ranging from 1:5000 to 1:25000 in scale (Petkovic et al, 1997). Schell (1997) derived the road geometry from geographic database at the scale of 1:10000 in the TRIAD (Traffic Information and Route Guidance Inter-Agency Database of West Sweden) project. Ditz suggested a scale of 1:2,250,000 as the lowest scale level for an Interactive Cartographic Information System (ICIS) of Austria since this scale can provide an overview of Austria (Ditz, 1997). One can see that the use of scale mentioned above differ from each other in a quite large extent. Different scale was used in different countries for different applications. From the above, it was suggested that the lowest scale level of a navigation system would better be able to cover the whole area of the local country.

For the working scale, Kim et al (1995) suggested to use 1:5000 digital road map for the development of vehicle navigation systems in Korea. They stated that this scale was suitable for the urban area, where there are often changes, high traffic density and road density. The scale 1:5000 is also the largest scale level used by Petkovic et al (1997) for the VNav mentioned before. One cannot deny that different countries should have different design of vehicle navigation system. Application for use of scales in Hong Kong will be discussed in Chapter Four.

Nowadays, the advent of computer technology has revolutionized the way cartographers produce maps. Some major digital road map suppliers have put much
effort in developing a map base for navigation. Two major digital road map suppliers are quoted as examples, which are Etak and NavTech.

- **Etak**

Etak Corporation of Menlo Park, California, is a digital map company that focuses on producing and distributing highly accurate digital road maps known as EtakMaps (Zavoli, 1989). Etak, which started with the maps for the Etak Navigator vehicle navigation system in the early eighties, has been producing digital road maps for more than ten years. EtakMap provides a format called MapBase which can be imported into most commercially available Geographic Information System (GIS) packages and thus can enhance the function of the navigation system such as path finding and location searching. The EtakMap has accuracy equal to 1:24,000 scale topographic map in metropolitan areas, while the accuracy in rural area is equal to 1:100,000 scale maps. The coverage for EtakMaps is extensive that all of the United States is covered in one of the versions. Besides, it has coverage in France, Germany, Japan, Canada, Hong Kong and the Netherlands.

- **NavTech**

Navigation Technologies Inc. (NavTech) of Sunnyvale, California, is a producer and provider of fully navigable digital road maps known as NavTech maps. NavTech has developed their databases from the beginning to support navigation functions such as map matching, path finding and route guidance (Sweetman and Collier, 1993). The first database was released in 1991 and now the databases are available in many major US cities such as San Francisco, Los Angeles, Chicago, Washington D.C., Orlando and Miami. They are guaranteed to be 97% complete and accurate both in position (better than 15m) and in the correctness of the restrictions and geometry of the road network.
As a whole, one can see that the visualization on screen offers many functionalities. For example, data can be arranged in different layers such that different levels of display can be defined by scale or by the selection of the user. Different levels of different scales, contents and generalization will be shown as the user zooms in and out. Different area can be viewed by zooming in and out or by scrolling with a scale level. Important information such as traffic readjustment and places of traffic accidents can even be shown in blinking symbols or text in order to arouse the user’s attention.
CHAPTER 3

FACTORS TO BE CONSIDERED IN DESIGN OF DYNAMIC
MAPS FOR VEHICLE NAVIGATION

3.1 Visual Variables

Maps are constructed from visual variables which could be static or dynamic. This session discuss static visual variables while dynamic visual variables will be discussed in the next session. In fact, design of map contents can be improved by adjusting their graphic characters in order to represent them in an effective way (Robinson et al, 1995). Basic graphic elements include point, line and area. Appearance of the basic graphic elements can be changed to be more or less distinctive and prominent by altering the primary visual variables which include shape, size, orientation, and color. Those variables are classified as static ones.

Among the static visual variables mentioned above, color is a very important element in visual phenomenon (Robinson et al, 1995) and thus will be discussed in a more detailed way. It can be presented in many ways by varying hue, value and saturation (chroma). The use of color in the design of the map should be thoughtfully considered in order to allow effective information transfer to the user. According to Jute (1993), no color is ever seen in isolation and thus it is the designer's responsibility to choose only those colors which will carry the message most effectively. That may be achieved by colors which work together harmoniously or by a selection of riotous contrasts. Stronger contrast could increase the prominence of the graphic elements. Strongest contrasts are produced by the three primary hues (red, blue and yellow), in which the complementary pairs produced by them are an easy design choice. For example, Red-orange and blue-green provide a warm-cold contrast, yellow and violet creates a light-dark contrast, while other combinations provide contrasts in between. Therefore, information with greater importance could
be produced by stronger contrast with the background, thus resulting in greater prominence. Another way to achieve this is to relate the importance of the information to the “universal order of color” defined by Hans Eysenck in 1941 which was later confirmed by Porter’s modern study in 1977. The “universal order of color” is blue, red, green, purple, yellow and orange, with blue being the most preferred hue and orange the least preferred one. This order of hue is known with fair accuracy. Lastly, conventions of color could also be used, for example, water represented by a blue color and forests by a green color.

### 3.2 Dynamic Variables

As mentioned before, visual variables could be static or dynamic. According to DiBiase et al (DiBiase et al, 1992), static maps are constructed from static visual variables within two or three spatial dimensions, in which static visual variable was discussed in the previous session. 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. Three modes of cartographic expressions in dynamic displays were realized by the authors, which are animation, sonification and interaction. Animation is the illustration of motion created from a sequence of still images to give the impression of motion; sonification is the representation of data with sound and interaction is the empowerment of the viewer to modify a data display. Arikawa called the maps he produced the dynamic maps because “the appearances of maps are dynamically changed by users’ changing their ad hoc queries and operations for the visualization of the data selected by the ad hoc queries on graphical user interfaces.” (Arikawa, 1994)

Koussoulakou (1990) found out that in the case of dynamic natural phenomena, animated maps convey information about dynamic objects faster than their static counterparts. Ing (1997) also stated that “…dynamic variables are not only valuable for designing the appearance and behavior of objects or simulated natural
phenomena within an animation. They are also valuable and important for the sequence design and the dramaturgy of the whole cartographic animation.” According to DiBiase et al (1992), there are three kinds of dynamic variables used for animated mapping. They are:

1. Duration

Duration is the length of time a scene is displayed. It can also be applied to the period of the cycle, i.e. the interval between repetitions of a phase. The simplest application of controlling period duration is in the binary cycling of on-off used in “blinking”. It can enhance the prominence of small point features without the need for large symbols. One good example is done by Monmonier in 1992 (Monmonier, 1992), who applied this technique to highlight individual categories of a choropleth map to draw attention to regional patterns.

2. Rate of change

Rate of change is the difference in magnitude of change between scenes / unit time for each scene (or \( \frac{m}{d} \)), and it can be constant or variable. If there is no change, \( m \) will be zero and thus rate of change will be zero. Assuming that neither \( m \) nor \( d \) is zero, either or both can be controlled to produce an increasing, constant or decreasing rate of change.

3. Order

Order is the sequence of scenes. Scenes can be arranged in chronological order or magnitude order. According to Ing (1997), order is used to guide the user from known to unknown thematic, spatial and temporal information. Sequences are ordered by logical relationships to support understanding.
3.3 Exploratory Acts

Similar to the static visual variables used in static graphic presentation that mentioned in the previous session, exploratory acts are exploratory variables in the animated cartographic environment. This idea is illustrated in Figure 3.1 in which two components of cartographic visualization, exploration and representation, were illustrated. The main difference between the two components is that presentation is generally concerned with known information while exploration is related to the discovery of unknown information. Exploratory acts provide tools for exploration in animated cartographic environment. A set of exploratory acts has been defined to stimulate visual thinking in the process of exploration by Jiang (Jiang, 1996)(Figure 3.2), which are described as follows:

- Blink.
  Blink refers to the act of blinking at a certain frequency. It is also termed as "flash", in which this terminology was used in this study. It attracts attention when it is applied to some object in the map space.

- Highlight.
  Highlighting shows up selected areas or object categories of a picture or photograph by making them lighter. It is another method in order to let users focus on some area over the map space, while fade-out effect is the opposite of highlight.

- Zoom in/out.
  Zoom in/out changes the size of an object. Zooming-in magnifies the object and gives a more detailed view of it, while zooming-out shrinks the object and provides an overview of the complete pattern.

- Pan.
  To pan is to change the position of an image relative to the monitor screen.

- Drag.
  Dragging means picking up an intended object and putting it in another position for further exploration.

- Click.
  Clicks include single-click and double-click. Both of them are basic cursor act. Usually, other exploratory acts start with the primary click.
Figure 3.1  Two tasks of visualization --- presentation and exploration. (From Jiang, 1996)

Figure 3.2  Exploratory acts for exploration. (From Jiang, 1996)
3.4 Map Complexity

Map reading process is an important issue when designing a map. Since 1970s, much research has been done in this area in order to improve map design and increase the overall efficiency of map use. With the knowledge of the perception experiences most people have when they read the map, the map designer can have better control over the decision of map contents and expression grade. As mentioned before, this is an important issue during map design process and this can be done by the study of map complexity. The map complexity test was used to determine the map contents and especially their expression grade in this study.

3.4.1 Definition of Map Complexity

Although much research has been done in the study of map complexity, there is still no unique definition of the term and this has hampered the progress of understanding in this issue. In fact, there are different concepts of map complexity and thus applying to different aspects of the map. However, different interpretations of map complexity have led to difficulties in their applications. As a result, one should have a clear outline of the definitions of the term before applying it.

One way to achieve this as the first step is to refer to a dictionary. Since complexity is generally referred to the state of being complex, definition of complex must be considered. Complex, as an adjective, has the following definitions from several dictionaries:

- “Composed of two or more separable or analyzable items, parts, constituents, or symbols; having many varied interrelated parts, patterns, or elements and consequently hard to understand fully.” (Webster’s Third New International Dictionary, 1976)

- “Consisting of many different parts or processes that are closely connected; difficult to understand or deal with.” (Longman Dictionary of Contemporary English, Third Edition, 1995)

- “Made up of (usually several) closely connected parts, i.e. one containing subordinate clauses; difficult to understand or explain because there are
many different parts. (Oxford Advanced Learner’s Dictionary of Current English, 1989)

One can see that the above definitions of complexity represent two points of view. One is related to interconnectedness and the other is related to ease of understanding. Fairbairn summarized this concept in a sentence: “...the intrinsic complexity of the subject matter of the map is related to the cognitive processes of understanding the map, whilst graphical complexity is more closely related to the visual impact of the map and to the perceptual processes of viewing it.” (Fairbairn, 1997) These two points of view are understood by Brophy (1980) as visual map complexity and intellectual map complexity respectively. He stated that “...visual map complexity is that which is a direct consequence of the spatial differentiation of the graphic content of the map, while intellectual map complexity is that which is due to the meanings or significations contained in or ascribed to the map symbolism.” In other words, visual map complexity affects map perception and is affected by mapped distribution, while intellectual map complexity is related to cognition, map interpretation and analysis.

Brophy also indicated that the two types of complexity should not be independent of each other. Rather a relationship exists between them as the intellectual content of map is expressed through the graphic symbols. In quantitative sense to measure map complexity, he suggested that “a continuum of map complexity exists which ranges from near zero to near infinite. Moreover, different maps, i.e. different symbols depicting different data, may have a similar level of complexity on a graphic and/or an intellectual basis.” Cartographers should not be seeking for the least map complexity since visually less complex does not necessarily imply increased effectiveness as pointed out by MacEachren in 1982. Rather they should reach for the optimum complexity instead of least possible complexity.

In fact, the two types of complexity correspond to different stages of cartographic communication and two stages can be defined. One is map reading and the other is interpretation and analysis. According to Morrison (1976), map reading refers to processes involving perception and/or cognition of information of the map.
whereas interpretation and analysis refer to processes involving information interaction acquired from the map with previously held information and adjustment of a receiver’s cognition of reality as a result of this interpretation.

Obviously, visual map complexity is more important in map reading while intellectual complexity is more important in interpretation and analysis. One may say that we should pay more attention to visual map complexity since cartographers could have greater control over it. Contrary to visual map complexity, intellectual map complexity is varied and difficult to measured. This is because different map percepts would have different cartographic training experience and background, leading to varied intellectual ability and capacity. A percipient may even have different intellectual ability at different time since he/she may be interested in the map content at one time but bored at another time. Moreover, it seems impossible to quantify phenomenological complexity as ideas and concepts are difficult to compare.

Thus, it is concluded that when determining map complexity, attention must first be directed to visual aspect which can be subjected to measurements. In fact, “visual aspect of map complexity is related primarily to pattern geometry within the map itself” (MacEachren, 1982) and map complexity may be defined as “...the spatial variance in map pattern” and be measured as “... the internal organization or dependence in map pattern”. (Muehrcke, 1972)

Another slightly different definition of map complexity is described by Castner and Eastman (1985). They defined map complexity in a way that more attention is paid on the role of the percepts. Three types of map complexity is proposed as follows (Eastman, 1977):

- **Stimulus complexity** – described as some property of the map which renders it somewhat indigestible to the perceptual and cognitive processes; it measured the informational content of the map.
- **Functional complexity** – related to the map use task and the user’s experience, leading to a less than optimal processing of a given task.

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• Perceived complexity – reflected the visual complexity and its effect on
the user with respect to the user’s subjective assessment in a given
situation.

They stated that perceived map complexity is the most useful measure of map
complexity among the three. They measured this by studying how the eyes moved,
instead of where the eyes moved in a map reading experiments, in which details will
be discussed later on in this review.

3.4.2 Map Complexity Models

One attempt to measure map complexity described by Brophy in 1980 is to
regard map as a gravity potential model, in which the visual complexity is claimed to
be related to the potential surface’s variability. In the author’s view, interactions may
occur between visual masses in a map, and they can be simply described by a visual
analog of Newton’s Universal Law of Gravitation. It is believed that the Newton’s
Law with respect to forces together with the concept of potential provides a useful
hint for understanding the visual perception of map.

First of all, one has to have some understanding of the Newton’s Universal
Law of Gravitation. According to Newton’s Law, any two masses, let’s say $m_1$ and
$m_2$, at coordinates $(x_1, y_1)$ and $(x_2, y_2)$ respectively, will attract each other with a force
$F$, which is defined as below:

$$F = K \frac{m_1 m_2}{r_{12}^2}$$

where $F$ = force of attraction between $m_1$ and $m_2$;
$K$ = constant;
$m_1$ = mass of body one at $(x_1, y_1)$;
m_2 = mass of body two at $(x_2, y_2)$;
\[ r_{12} = \text{separation distance between body one and body two, which is equal to:} \]

\[ \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \]

If a group of masses act on either one of the two bodies, say \( m_1 \), the total axial components of the forces, \( X \) and \( Y \), exerted on \( m_1 \) are:

\[ X = K \sum_{i=1}^{n} m_i \frac{(x_i - x_1)}{r_i^3} \]

\[ Y = K \sum_{i=1}^{n} m_i \frac{(y_i - y_1)}{r_i^3} \]

Then the total effective force acting on \( m_1 \) (\( F_{m_1} \)) can be determined by \( X \) and \( Y \) by the following equation:

\[ F_{m_1} = \sqrt{X^2 + Y^2} \]

Associated with gravitational force stated above is the gravitational potential energy. In fact, whenever two or more masses are retained at a separation, gravitational potential energy exists and it is equals to:

\[ V_{X,Y} = K \sum_{i=1}^{n} \frac{m_i}{r_i} \]

where

- \( V_{X,Y} = \text{gravitational potential energy at a point;} \)
- \( K = \text{constant;} \)
- \( m_i = \text{i_{th} mass in system;} \)
- \( r_i = \text{distance of mass i from the point under consideration.} \)
After some understanding of the Newton’s Law, let’s take a look at the relation of the gravity model with visual perception. If we treat map as a visual spatial system, the gravity model described above can help us in understanding map complexity. Similar to the gravity model, map (either in hard or soft copy) concerns about visual mass. The mass of any object in a map is determined by the object’s size, shape and tone. Larger and darker object will have greater mass than a smaller and lighter object.

In addition to the above analogy by Brophy, much research has been done to prove that forces and potentials do exist between the elements in a map. Kohler in 1967 theorized that “a physical Gestalt is, among other things, a grouping of forces which operate upon the topography of its occurrence”. (Kohler, 1967) Later Arnheim described these forces as having magnitudes and directions and as being real forces both psychologically and physically (Arnheim, 1974). Yokose and Uchiyama also proved that graphical field forces are directly proportional to the stimuli magnitude and inversely proportional to the square of the separation distance (Yokose and Uchiyama, 1951). Comparing the results of the above research with the model proposed by Brophy, it seems reasonable to infer that perceptual forces do exist in map and they are generally in accordance with the gravity model.

In addition to the relation between visual perceptual and the gravity model with respect to perceptual forces, Brophy also stated that there is another correlation with respect to the center of mass or “center of gravity”. Evidence showed that visual center of gravity do exist in a figure (Arnheim, 1974; Zusne, 1970; Kaufman and Richards, 1969). It is also possible for a figure to have multiple centers of gravity if the figure is composed of several forms. According to Brophy, “...centers of gravity are points which attract attention and thereby determine the location of eye fixations and occurrence of intervening eye movements. These activities then occur so as to resolve and organize the differential forces existing within the display.” (Brophy, 1980)
Then one should take care of the figure’s potential since center of gravity will provide peak of potential value. The distribution of potential energy as a surface can be inferred by calculating the gravitational potential energy at a series of points. Once the potential surface is constructed, it can provide hints about the likelihood of eye movements and eye fixation points, where peaks of potential value may correspond to more important, interesting and informative area.

From Brophy’s research, we may conclude that map complexity can be inferred by the graphic differentiation across the map, which is reflected by the gravity potential model as a function of the distance between symbols and the mass of the symbols. The variability of the potential surface is determined by the size, shape, tone or value of the map symbols plus the spatial variability of the map symbols’ distributions. More variable surface will lead to increased viewer attention, increased information to be processed and decreased easiness of the information to be understood.

The second method to measure map complexity is described by MacEachren in 1982. In his study, he aimed to examine the subjective complexity of isopleth and choropleth maps, then to develop a physical measure of complexity. He produced a large sample of stimuli (forty choropleth and forty isopleth, resulting in a total of eighty maps) such that it is sufficient enough to cover a board range of values. In producing the maps, the area to be represented was not mapped at the conventional orientation in order to reduce the possibility that impressions of complexity will be influenced by familiarity with the area to a minimum.

The first part of his study was to measure the subjective complexity, and it was done by using a technique called psychophysical scaling. There are two types of psychophysical scaling: direct and indirect. In indirect scaling, a hypothetical psychological dimension is required to convert the ordinal data to interval scale data and it requires more steps moving from the raw data to the final scale. However, in direct scaling, the quantitative property to be measured is defined in the instructions to the subjects. As a result, fewer steps are required between the raw data and the final
scale, making it more easily to be applied and thus the author has chosen this technique.

According to Engen (1972), magnitude scaling provides the best consistency among all forms of direct scaling, where magnitude estimation is the most direct method of magnitude scaling. In magnitude estimation, the respondent is required to match a number directly to each stimulus according to the perceived magnitude. There are two approaches to achieve this. The first approach is to provide the respondent with a standard stimulus, then the respondent relates each other stimulus to it. However, the choice of the standard stimulus may introduce bias in the test which is not suggested. The second approach described by Stevens in 1956 doesn’t involve any standard. Instead, the respondent is allowed to choose any number to represent the magnitude to the first and every subsequent stimulus. In this way, the bias introduced by the arbitrary standard can be avoided and thus this method is chosen by MacEachren in his study.

After looking up the approach the author has taken, the procedures that he followed are then examined. The eighty maps were arranged in random order and were presented to the respondents. His instructions of the test to the respondents were extracted as follows, where key points are highlighted in italic fonts:

“You have each been presented with a set of maps arranged in random order. You will be asked to give me some information about how complex the maps appear to be. Before I explain more specifically what you are to do, I would like you to sort through the maps to get an idea of the range in complexity that exists in the set. By complexity I mean how intricate or involved the maps appear to be.

What you are to do is to indicate how complex, or how complicated or involved, each map appears to be by assigning a number to it. Assign any number that seems appropriate to the first map. Then, one at a time, assign numbers to each additional map that reflect your impression of the map's complexity. There is no limit to the range of numbers that you may use. You may use whole numbers, decimals, or fractions. Try to make each number
match the intensity as you perceive it. Keeping in mind that there are no limits to the range of numbers you may use, if a map appears more or less complex than any of those before it, assign a number that indicates this. Do not go back to look at maps you have already rated.”

In the instructions, the author has included his definition of complexity, such that the respondents know what to measure. Moreover, much attention was paid in the words to stress that subjective complexity was to be measured. For example, he used “reflect your impression of the map’s complexity” and “match the intensity as you perceive it”. Also, no limit is set for the respondents. The respondents can simply sort through the maps to get an idea of the range of complexity and then mark each map successively. Decimals and fractions may also be used, providing the respondents with flexibility which may result in more accurate results.

After collecting the results from the respondents, the next step is to convert the raw data into the subjective complexity scale. To achieve this, one has to standardize the data and calculate the central tendency for each group of observers. According to Engen and Stevens (Engen, 1972; Stevens, 1956), the geometric mean is the most appropriate measure of central tendency.

To calculate the central tendency, one important procedure is to eliminate different ranges of numbers used by different respondents. A method is outlined by Engen in 1972:

1. Convert each response value to its logarithm.
2. Determine the mean value of each row (logarithm of the geometric mean of each observer's responses to all the stimuli).
3. Determine the mean of all values obtained in step two (logarithm of the grand mean of all the responses for all observers to all stimuli in the original data matrix).
4. Subtract each of the individual mean log responses in step two from the grand mean log response determined in step three.
5. Add the value obtained in step four to the row values obtained for each observer in step one.

After analyzing the raw data to get the subjective complexity, MacEachren then measure the objective complexity by considering the observed number of faces and vertices and original number of faces and vertices. However, it is not discussed in details here since it is only applicable to isopleth and choropleth maps.

Another way to measure map complexity is through the recording of eye movements. By analyzing the eye movement records, one can evaluate the subjects' visual and intellectual responses to the map. Several methods have been reported in the past decades (Kris, 1960; Shackel, 1967; Yarbus, 1967; Monty and Senders, 1976) and they can be classified into direct and indirect methods. Direct methods provide most accurate results but they may involve the attachment of devices, e.g. a lens with a mirror surface, directly to the eyeball which may cause discomfort to the respondents. Indirect methods, on the other hand, are more easily applied although they are less precise. They are especially suitable for cases where it has to replicate a normal reading situation. A study by Castner and Eastman in 1985 used two eye-movement parameters, fixation duration and interfixation distance to measure map complexity. Fixation duration indicates depth of cognitive processing while interfixation distance indicates extent of peripheral processing. A strong relationship was found between the two eye-movement parameters and the perceived map complexity. Duration of eye fixations increased with increased map complexity. As the author pointed out, "eye movements are an outward manifestation of visual/cognitive processing, and by examining how the eye moves, we can gain important information about the workings of this crucial process by which the reader confronts and understands the map". (Castner and Eastman, 1985)
CHAPTER 4

DESIGN OF DYNAMIC MAP IN VEHICLE NAVIGATION

In this study, the aim is to investigate the effective design of dynamic multi-scale maps for land vehicle navigation. In order to achieve this, various factors such as map complexity, static and dynamic visual variables have to be considered. Different prominences could be assigned to the contents according to the vehicle position by effective use of the static and dynamic visual variables. Effective symbols for navigation will also be designed. Some of the factors were determined during the design stage while the others were determined in map evaluation. The determination and implementation of those factors were examined in this chapter according to the map design process.

4.1 Design Principles

The main function of a map is communication (Board, 1967; Kolacny, 1970; Ratajski, 1973; Ormeling and Kraak, 1987; Robinson et al., 1995). A model proposed by Ormeling and Kraak (Ormeling and Kraak, 1987) summarized the cartographic communication process (Figure 4.1). From the model, one can see that the communication process starts with real world data which are collected, analyzed and portrayed in the form of a map. A view of reality was generated by the analysis and the perception of the map in the user’s mind (box 1’ in Figure 4.1). However, this view of reality usually deviates from the real world (box 1 in Figure 4.1) and that’s why box 1 and 1’ are only partially coincided. Accuracy and effectiveness of the cartographic representation determine for the most part how the two boxes depart from each other, in another words, how the mental representation departs from reality. Therefore, a good map design is essential as to provide effective communication from the map to the map user in order to minimize this deviation. As pointed out by Chen & Ye in 1997 (Chen & Ye, 1997), “map design is an important link in the process of map-making, and determines the quality and the appearance of maps.” In the
application of a land vehicle navigation system, one may say that the design of the user interface (which is mainly the map component) is mostly responsible for the success of the system. A good design of the map is especially important since the driver is in a divided attention environment. Effective information transmission from the map to user is vital under this hazardous environment.

Figure 4.1 Outline of the cartographic communication model (Ormeling and Kraak, 1987)
In order to effectively design and evaluate a map, knowledge about human perception must first be acquired. Three stages of visual information processing were identified by theories in cognitive science (Marr, 1982; Kosslyn, 1985), as shown in Figure 4.2. In the first stage of processing, a perceptual image was produced by discriminating (but not interpreting) graphic elements, such as color, lines and texture. In the second stage, these graphic elements were grouped into perceptual units which were stored in short-term memory. Lastly in the third stage, the perceptual units stored temporally in the short-term memory were interpreted with knowledge and then carried into long-term memory, if not displaced first by new information or otherwise purged. The broken arrow in the figure shows that information stored in long-term memory works as “working memory” to evaluate and comprehend details which kept in short-term memory.

Figure 4.2 Three-stage model of visual information processing, after Kosslyn (1985)
Oed (1989) also identified three steps of perception applying in animated cartography. According to Oed (1989), the first step of perception is to create a reference system for the definition of the own temporal and spatial position. In other words, sequence has to be introduced for proper orientation within a cartographic animation. In second step, a selective perception starts to identify objects which are important for life or personal interest. During this process unimportant details are filtered and those objects which the human has learned to recognize and which are important for the actual task are identified. Finally, the third and most important step of perception is recognition. This is almost a subconscious process which allows one to identify objects in less than a second just by perceiving characteristic features. With the knowledge of these three steps of human perception, some fundamental rules for the design of a dynamic map could be implied:

1. Support of spatial and temporal orientation (i.e. by a full-shot).
2. Support of object perception (i.e. by close-up, zooming of objects, still images), and
3. Support of semantic definition (i.e. display of characteristics, recognition).

As mentioned before, a good and effective design of the navigation map is indispensable to the success of a navigation system. 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. Map complexity may have an adverse effect on map effectiveness and at certain levels impede map communication (MacEachren, 1982). However, it is unlikely that all increases in map complexity will result in a corresponding decrease in effectiveness. Therefore, the complexity-effectiveness relationship should be examined carefully to produce an effective map. Other than the information to be put on the map, the design of the symbols as well as their arrangements are also critical factors to be considered. Although underlying principles of cartographic design for conventional maps are well established, those for navigation maps have not been well developed. One can see that a navigation map would be different from a conventional topographic map in the sense that it is dynamic while the latter is static.
Some basic functions and requirements of the digital map to be applied in vehicle navigation system suggested by Petkovic and Kajan et al (Petkovic et al, 1997) listed in Chapter 2 would be included in this study. For example, the map will be constantly updated as the vehicle navigates along the road by re-centering the map according to the vehicle's position. Multi-scale representations of details will be presented where users can change the scales and level of details by zooming in and out. Turn regulations and the vehicle's route between two locations will also be presented.

New concepts and design should be developed exclusively for navigation maps. One has to fully investigate how the information should be presented to be most effective to achieve better performance on navigation tasks. In this study, attention would be put on the use of dynamic effects applied in the map. Prominence of map contents would differ according to the vehicle's position. This was achieved by effective variation in the static and dynamic visual variables of the map contents. Examples of variations include the change of color or size of the map content and the flashing effect on it. Symbols which were made exclusively for vehicle navigation map were designed. Several sets of maps were produced using underlying principles of visual variables. Then they will be investigated by the perceived map complexity test to obtain an effective one.

4.2 Map Design Process

Map design is an important component in the process of map-making and it determines the quality and the appearance of maps (Chen and Ye, 1997). According to Hua (1997), it is necessary to make map product according to fundamental principle of cartography and to analyze the process of map design in great detail in order to achieve effective map information transmission. He decomposed the map design process into different task parts which are:

1. Acquisition of basic conditions.
   It consists of the acquisition of basic map information such as map area, map type, map theme, means of output and means of map use etc.
2. Decision of mathematic basis.
   The main task is to decide the scale and projection of designed map. Deciding scale has relation to the scope of map region and size of map product while deciding projection has relation to scope, shape of map region, map type and map theme.

3. Decision of map contents.
   To decide which map elements should be expressed on map. Map elements can be divide into two parts: thematic ones and basic ones. Thematic elements can be decided by combining map type with map theme. Basic elements will mainly be affected by map type and has not much to do with map theme. Therefore, the decision of map contents can be made by knowledge about map type and map theme.

4. Decision of expression grade.
   To decide how detailed that a kind of map element should be expressed on map. The main factors that affect the decision of expression grade are character of elements, quantity of map elements, map type, map theme and map scale etc.

5. Decision of symbol type.
   Map symbol can be divided into three kinds: point, line and area. The task of this part is to decide which kind of symbol type should be used to express each element displayed on map.

6. Design of map symbol.
   It includes the design of point, line and area symbols, together with the whole coordination among all map symbols.
   Design of point symbol: to determine the shape, size and color.
   Design of line symbol: to determine the shape, size (weight) and color.
   Design of area symbol: to determine to determine the color and pattern.

7. Process of map data.

8. Placement of name and map legend.
   Use of appropriate style and font for name placement and determine proper position of legend.

Design of the dynamic map will be discussed according to the processes mentioned above. Acquisition of basic conditions and decision of mathematic basis
will be discussed in session 4.3 and 4.4 respectively. Decision of map contents and expression grade will be discussed together in session 4.5. Design of symbol type and map symbols actually can be done by the study of both static and dynamic visual variables that will be discussed in the session 4.7. When the eight task parts have completed, a map is designed and produced. This map then has to be evaluated for its effectiveness, i.e. to undergo map evaluation, and this will be discussed in CHAPTER 6.

4.3 Acquisition of Basic Conditions

It consists of the acquisition of basic map information such as map area, map type, map theme, means of output and means of map use etc. Map data was obtained from the Land Information Centre (LIC) of the Government of the Hong Kong Special Administrative Region, China. Other features for driving such as turn restrictions at intersections and landmarks along the roads were added in as well (Choi, 1998; Driver’s atlas: Hong Kong, 1998; Hong Kong Driving Guide, 1998; Petkovic et al, 1997; Sena, 1997). The map area was selected between Wan Chai and Causeway Bay. This was chosen because the GPS data collected in this area provided the best performance among those we have in hand. The map is designed for land vehicle navigation and it is a dynamic one with multi-scale levels. For the means of output, the map can be stored in a notebook computer, which is connected to a D.R. system and a GPS receiver, and it is used inside the vehicle.

4.4 Decision of Mathematic Basis

The main task is to decide the scale and projection of designed map. As mentioned in CHAPTER 2, the lowest scale-level of a navigation system should be able to cover the whole area of the local country. For Hong Kong, a scale of 1:200,000 may be suitable to be the lowest scale-level since this scale can already covers the whole territory and smaller scale may be difficult to read. This scale would
be a good one to show start point location and destination location in one display no matter where the two points are located. By one display, we assume the output device will be a notebook computer with display size ranging from ten to twelve inches in diagonal dimension. This size is the majority one among notebook computers available nowadays. Furthermore, this size is similar to an A4 size paper, which is the size used by the government to display the whole Hong Kong area in one sheet with the scale of 1:200,000. Since display size is a function of the display device, it is not possible to make the scale suitable for all means of output. Therefore, this assumption is made as a tradeoff. For the scale-level to be used during driving, 1:5,000 may be suitable since the transportation network in Hong Kong is quite complicated and may require a larger scale to put details in. As suggested by Ditz (1997), maps for navigation system should provide four levels of different scales. In our case, the smallest scale-level is 1:200,000 while the main scale-level for navigation is 1:5,000. Therefore, it is proposed to set the other two scale-levels as 1:2,500 and 1:10,000, which are the zoom in and zoom out effects of the main scale-level respectively. Compared with the scale-level 1:5,000, the scale-level 1:2,500 provides a more detailed view which may include street names and building names, while the scale-level 1:10,000 provides a broader view for the user with much less details in. Much generalization was involved in the three scale-levels, where more detailed description was put in session 4.9, the multi-scale representation. However, the 1:200,000 scale-level for use in pre-planning stage would not be included in this study. The focus would be put on the working scale-level to be used in the driving stage, which are 1:2,500, 1:5,000 and 1:10,000. Also, the projection type is Universal Transverse Mercator (UTM) since the map we use is in large scale.

4.5 Decision of Map Contents and Expression Grade

As mentioned before, map elements can be divided into thematic ones and basic ones, where only the latter ones will be included in the maps for vehicle navigation as in this study. For the basic elements to be contained, it is mainly affected by map type but not map theme. Knowledge about the map type was
acquired by the study of different driving guides and literature about the cartographic presentation for vehicle navigation (e.g. Driver's atlas: Hong Kong, 1998; Hong Kong Driving Guide, 1998; Petkovic et al, 1997; Sena, 1997). Therefore, keeping in mind that the maps were designed for vehicle navigation, only those contents which are contributive to the navigation process would be contained.

The decision of expression grade was to decide how detailed that a kind of map element should be expressed on a map. Attention was focused in this area in this study. Different designs were made for map elements. An example was illustrated in Figure 4.3, where different expression grades were made for the presentation of a landmark, the Central Plaza. In Figure 4.3a, the presentation of the landmark was shown by its name in text. In Figure 4.3b, the presentation of landmark was shown by a perspective symbol which replicate the outlook of the building. In Figure 4.3c, the presentation of the landmark was shown by both the text and the perspective symbol, which was a combination of Figure 4.3a and 4.3b. Different expression grades were used in the three figure for the same map content, the landmark "Central Plaza". The designs were evaluated by the respondents to get an effective one for vehicle navigation. The evaluation was done by a map complexity test suggested by MacEachren (1982).

In fact, the decision of map contents and their expression grades was related to map complexity. Detailed explanation of map complexity as well as the methods for measurements were discussed in CHAPTER 3, while the selection of method and the implementation to be applied in this study will be put in session 4.6.
Figure 4.3a  Presentation of landmark by text.

Figure 4.3b  Presentation of landmark by perspective symbol.

Figure 4.3c  Presentation of landmark by both text and perspective symbol.

Figure 4.3  Different representations of landmark.
4.6 Consideration of Map Complexity

One way to determine the contents to be contained in the map as well as their design is through the study of map complexity. As mentioned before, there are three main types of methods for measuring map complexity. The first one is the visual analogy of Newton's Universal Law of Gravitation proposed by Brophy in 1980. It is believed that map complexity can be inferred by the graphic differentiation across the map, which is reflected by the gravity potential model. Increased potential value corresponds to increased likelihood of eye movements and eye fixation points, and centers of gravity are points which attract attention. However, it seems that this potential model is only applicable to static map. For dynamic map in our case, the contents to be displayed would be changed as the vehicle navigates. Thus the potential value would also be changed and it is not possible to form a unique potential model. Indeed it would be a series of potential model with different values where the total number of models may be an infinite number.

The second method to measure map complexity is through the recording of eye movements. By analyzing the eye movement records including fixation duration and interfixation distances, one can indirectly evaluate the subjects' visual and intellectual responses to the map. However, the recording of eye movements involves either an attachment of devices directly to the eyeball that would be uncomfortable to the subjects or an expensive specialized equipment with photoelectrically sensing of the reflection of infra red light from the eyeball. Since the test may involve a considerably large number of test subjects and would better be an economic test, this method of recording eye movements seems inappropriate.

Furthermore, the above two methods only provide a numerical result of map complexity based on comparison. One can only get a range of map complexities from the results. However, the aim of this study is to seek for the suitable but not the least or highest map complexity. The aim is to find out the suitable map complexity level for the most effective transmission of cartographic information to the users. The above two methods do not provide any clues for the effective design. Therefore it is concluded that the above two methods are not suitable for this study. Finally, it
comes to the third method to measure map complexity which is described by MacEachren in 1982 and similar method is used in this study.

According to Wood (1972), techniques of “asking the user” must be employed as a guide to selection. Therefore, a test was firstly carried out to determine the users’ preference on some fundamental variations of map design in order to narrow down the numerous combinations of different designs. Respondents would be asked what representations they prefer to be contained as well as the helpfulness of different dynamic effect in the map. Example of questions of preference is road network with center-lines or roads with both sides shown; while example of questions of helpfulness includes the helpfulness of using perspective symbol for landmark. At the end of the test, they are provided with an opportunity to add in extra details that are not inscribed in the map by brainstorming. This is similar to the “thinking aloud” technique described by Heidmann and Johann (1997). The questionnaire is conducted in this way in order to provide the opportunity to contain contents that are not included but preferred by the users.

With the users’ preference obtained in the test, several sets of multi-scale maps with different representations could be produced. A test according to the method described by MacEachren (1982) (discussed in CHAPTER 3) is then implemented to obtain the effective map complexity. First of all, the respondents would be asked to take a look at all sets of the multi-scale-level maps to get an idea of the range in complexity. Then, the respondents would be asked to view at individual map at a time and they are required to assign a number to it. There is no limit of the range of the numbers that they can use, and greater number represents more complex map which is less effective for navigation. After that, we would get different sets of numbers with respect to the different sets of maps. The data would next be analyzed according to the method described by Engen (1972). At the end, we would come to a set of multi-scale maps with the lowest map complexity assigned by the users. i.e. the one which work most effectively.
4.7 The Use of Visual Variables for Map Design

4.7.1 The Use of Static Visual Variables

As stated before, appearance of the basic graphic elements can be changed to be more or less distinctive and prominent by altering the primary visual static variables which include shape, size, orientation and color. Among all the static visual variables, color is a very important element in visual phenomenon (Robinson et al, 1995). The road which the vehicle is navigating in could be assigned with a strong contrast with the background, or it could be assigned with different color for better differentiation with other roads. The roads which the vehicle is not navigating in as well as the buildings along them could be assigned with lower value and saturation. More distinctive and prominent effect were provided by highlighting effects which include increasing the symbol size, font size of building name and road name, line thickness of road network and changing the color of the elements. Some of the highlighting effects by varying the static visual variables were shown in Figure 4.4 to Figure 4.8. Less distinctive effect were provided by adverse assignments to the attributes of features. For example, the road name circled in Figure 4.7a was assigned with a low grey value. When the vehicle approaches that road, the road name would be highlighted by increasing the font size plus assigning a red color to it in order to increase its prominence (as shown in Figure 4.7b). Different uses of static visual variables and their usefulness for varying the prominence were determined in the map evaluation.
Figure 4.4a  Symbol (circled in pink) before the highlighting effect.

Figure 4.4b  Symbol (circled in pink) after the highlighting effect.

Figure 4.4  Symbol highlighted by increasing the size.
Figure 4.5a  Building name (circled in pink) before the highlighting effect.

Figure 4.5b  Building name (circled in pink) after the highlighting effect.

Figure 4.5  Building name highlighted by changing the color.
Figure 4.6a  Building name (circled in pink) before the highlighting effect.

Figure 4.6b  Building name (circled in pink) after the highlighting effect.

Figure 4.6  Building name highlighted by increasing the size.
Figure 4.7a  Road name (circled in pink) before the highlighting effect.

Figure 4.7b  Road name (circled in pink) after the highlighting effect.

Figure 4.7  Road name highlighted by increasing the size and changing the color.
Figure 4.8a  Road segments (circled in pink) before the highlighting effect.

Figure 4.8b  Road segments (circled in pink) after the highlighting effect.

Figure 4.8  Road segments highlighted by changing the color and increasing the line thickness.
4.7.2 The Use of Dynamic Visual Variables

The variables mentioned above are related to static maps, while the map going to be developed is a dynamic one. While applying them in our case, more concern about dynamic variables has to be taken into account.

As mentioned before, blinking technique is believed to be effective in drawing user's attention. Thus, important information such as road turning restrictions could be displayed in blinking format. When creating the blinking function, the period duration is held constant since changing the period can result in an appearance of more or less urgency (MacEachren, 1995). The duration of each period was carefully controlled since too short a period may be difficult to be seen or too long a period would lose the effect of blinking.

Another dynamic variable, rate of change, is mostly related to the rate of receiving GPS data in our case. As the vehicle navigates, the vehicle's position is determined once the GPS data is received, and then the position is refreshed in the map display. The corresponding part of the map is displayed according to the position of the vehicle. Therefore, the rate of change of the map display is a variable, depending on the rate of GPS data receive. Since the scene is displayed according to the vehicle's location, the last dynamic variable, order, obviously relates to the driving direction of the vehicle.

The three modes of cartographic expressions in dynamic displays, i.e. animation, sonification and interaction, described by the DiBiase et al (1992) are applicable in vehicle navigation display, where animation and interaction were considered in this study. 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. The multi-scale representation will be discussed in session 4.9.

4.7.3 The Use of Exploratory Acts

As mentioned in the previous chapter, exploratory acts provide tools for exploration in animated cartographic environment. There are six exploratory acts defined by Jiang (1996), which are flash, highlight, zoom, pan, drag and click. Flashing effect would be applied to map contents which were considered to be most important in vehicle navigation. Highlighting effect would be applied to the central area of road network defined by the vehicle's position in order to give the users a better perception. Flashing and highlighting effects to be applied in the dynamic map would be described in a more detailed way in the next chapter. Zoom functions were used so as to change the scale-levels of the map, and it is an important function in the multi-scales representation of the dynamic map. Zooming-in would give a more detailed view of the area in a larger scale-level while zooming-out would give a broader view of the area with fewer details in a smaller scale-level. Panning is also allowed in order to change the displayed position of the map as desired by the users. Dragging of objects is not expected to be performed with the map since users were not supposed to change the geographic position of any map content. Clicking on an object would pop-up its database which stores the detailed information of the object. For point object, examples of information include its coordinates, symbol style and symbol size. For line object, examples of information include its bounding coordinates, length and line weight.
4.8 Design of Symbols for Vehicle Navigation

To make a map presentation effective, symbols have to be carefully designed and chosen (Robinson et al., 1995). Since there are almost unlimited varieties of graphic signs, some guidelines will be followed during the design stage of symbolization.

Castner and Forrest carried out a visual search experiment using tourist symbols (such as “hospital” and “park” that will be contained in our case) in 1985 (Castner and Forrest, 1985). Later on Forrest produced some guidelines in for the experiment in order to clarify the principles and results (Forrest, 1998). In his conclusion, he wrote:

- Symbols should be grouped by using a small number of distinct colors where possible;
- Symbols should appear to be approximately the same size;
- Symbols should be framed in a set of simple geometric outlines, especially if color groups are not practical; and
- Identification is more accurate with pictographic symbols, but these can be relatively simple images.

New types of symbols which include blinking ones, symbols represented by official logos of the buildings (an example was shown in Figure 4.9) and symbols with three-dimension perspective (an example was shown in Figure 4.10) were designed. The direction restriction symbols were designed to replicate those by the Transport Department which are used as road signs (Figure 4.11). Shapes and colors were followed such that the users can relate the symbols to the road signs easily. The symbols will later on be tested for their effectiveness in map evaluation.
Figure 4.9  Symbol represented by official logo of the building
Hong Kong Convention and Exhibition Centre.

Figure 4.10  Symbol with three-dimension perspective.

Figure 4.11  Symbol replicating the road sign by the Transport Department
4.9 The Design of Multi-Scale Representation

The maps used in this study were derived from the digital map series of the local Land Information Centre (LIC). 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 4.12), where the maps with scale of 1:2500 (Figure 4.13) and 1:10000 (Figure 4.14) could provide a zoom in and zoom out effect respectively. For example, one could only show the centre line of road in 1:10,000 scale-level while both sides of the road might be shown in 1:5000 scale-level. Whenever the users use the zoom function, different map layers would be stimulated. A set of maps with different complexities was design such that the users would be provided with different levels of contents and representation by zooming in and out. The effectiveness of the design should be investigated during the map evaluation process.

With the possibility of changing the map scale, different levels of feature and text detail were provided at the same time. Since it is not necessary for the map to present all information on a single image, one could fit as many features and their names as possible using different levels of contents.

The study area was between Causeway Bay and Central in the Hong Kong Island. According to the Road Classification System by the Transport Department, roads in the study area are classified into four categories - Urban Trunk Road (UT), Primary Distributor (PD), District Distributor (DD), Local Distributor (LD). The classification is mainly based on their designed functions which was declared by their name and is supplemented by the road construction standard and the traffic management system. An Urban Trunk Road serves to connect the main centers of population; a Primary Distributor forms the major network of the urban area; a District Distributor links districts to the primary distributors. For the Local Distributor, the roads within districts link developments to them. Different color & line thickness were assigned to the road segments according to the classification and
scale-level. Roads with higher rank will be assigned with thicker lines and with color of higher value.

Figure 4.12  Map with scale-level 1:5000
Figure 4.13  Map with scale-level 1:2500
Figure 4.14  Map with scale-level 1:10000
CHAPTER 5

CARTOGRAPHIC IMPLEMENTATION

5.1 Working Platform

The working platform of this project was based on MapInfo Professional version 5.0 together with MapBasic version 5.0. MapInfo Professional is a software for mapping and geographic analysis which allows users to better visualize and analyze data. MapBasic is used in conjunction with MapInfo Professional. It is a BASIC-like programming language to create custom MapInfo application in order to embed more mapping functionality into the software. Some features of MapBasic which are beneficial to this project are extracted from the homepage of MapInfo Corporation and listed as follows, where the use of those features to program the dynamic environment will be described in the next session:

- **User Interface:**
  - Create new menu bars, menus or menu items.
  - Create custom dialogue boxes with text boxes.

- **Geographic object manipulation:**
  - Create points, lines, polylines, text, polygons, buffers etc.
  - Edit and manipulate objects including reshape, object conversation, spilt, combine, erase.
  - Modify object styles.
  - Display maps from multiple layers, control display settings.
  - Find and geocode objects.

Coordinates of the positions of the vehicle were stored in a coordinates file. In order to simulate the use of an in-vehicle positioning system, real GPS (Geographic Positioning System) data that collected beforehand were used. Programs developed by MapBasic would read the vehicle’s position in the coordinates file and display the vehicle on the map. The MapInfo Professional interface contains functions which were extended by MapBasic. MapBasic would be running in the background, remaining as a hidden server to the navigation system. As a result, the user would
only see one application interface, in which would be user-friendly and easy to be used.

5.2 Preparation of Map Data

Map data for the road network was obtained from the local Land Information Centre (LIC). However, the data only contains coordinates of nodes which constitute the road network. Therefore, Arc/Info was used to build the topology and form the road network. Then the data was import into MapInfo Professional to suit its working platform. During the stage of import, plan projection was selected with meter as the working unit. Identity (ID) numbers were automatically generated for each road segment and stored in the database during this stage. The database stores the ID number of each road segment as well as its attributes such as the coordinates, line thickness and color.

Road networks with both sides of road shown and the road networks with center-lines were contained in different files. Therefore, they were imported into different tables in MapInfo Professional separately and to be displayed in different layers in latter stage (See Figure 5.1 and Figure 5.2). Every table in MapInfo would be consisted of four data files. Using the “ROAD” table as an example, it would be consisted of the following four files:

- ROAD.tab
  This file describes the structure of the table. It is a small text file describing the format of the file containing the data.
- ROAD.dat or ROAD.dbf or ROAD.xls
  This file contains the tabular data. It could be a database imported from other source such as dBASE, Microsoft Excel and Microsoft Access file.
- ROAD.map
  This file describes the graphic objects.
- ROAD.id
  This is a cross-reference file that links data with the objects.
Generalization was carried out with the road data in order to suit the needs for use in navigation. Map contents for the three scale levels were contained in different tables such that different map contents could be displayed according to the scale level in order to achieve the multi-scale representation. The list of tables for different map contents stored in MapInfo Professional was shown in Figure 5.3. Each of the table could be set to visible, editable, selectable and auto-labeling by activating the appropriate box, and vice versa. Map contents include road names, building names, turning regulations symbols, landmark names and landmark symbols. They were added into the map in different layers. Adding the features in different layers has the advantage that it would be more efficient in searching the features in close proximity of the vehicle for the highlighting effect and thus decreasing the calculation load for running the program. Moreover, data can be better arranged for the multi-scale representation since different scale-level would contain different contents. Two more layers were created in order to add background color to the sea, ground and road network for easier differentiation and better perception. One layer is used to add background color to the road network and it will involve in the dynamic program for highlighting the central area of the map. It was achieved by adding color polygons to the road segments and to the intersections as shown in Figure 5.4. It was done in this way in order to match up with the highlighting function. In the highlighting function, a central area was defined by the vehicle position. Road segments which fall within that central area would be highlighted in order to give better perception (Figure 5.5). The highlighting effect was done by changing the color of the road furnishings into a lighter value. Therefore, roads should be furnished individually by color polygons which were defined by the road intersections. Another layer was used to add background color to the sea and the ground. However, this layer was only used to furnish the map but would not be involved in the creation of the dynamic effect.
Figure 5.1  Table of road network with both sides of roads shown.

Figure 5.2  Table of road network with center-lines.
Figure 5.3 Map contents tables for the multi-scale representation.

Figure 5.4 Furnishment of road segments.
Figure 5.5  Background color of road network being changed in order to highlight the central area of the map.
5.3 Creation of the User Interface

The set of maps for evaluation was created using MapInfo Professional. MapBasic was integrated with MapInfo to embed more mapping functionality into the software, and especially to program the dynamic environment and to allow interactivity to the viewer. Some features of MapBasic that mentioned in the session 5.1 were applied. New user interface was designed and geographic object manipulation was applied in the dynamic map programming.

A menu bar was created in the MapInfo Professional user interface (Figure 5.6) in order to provide options for the users to select. As shown in the figure, an option “Demo” was created under the “Tools” pull-down menu bar. The “Demo” menu has five options which are:

1. “Restriction..”
   It is the function to display the restricted road area according to the current time. This function reads the system clock and then calculates the restricted road area according to the time schedule. Corresponding restricted roads will be highlighted.

2. “Start Normal..”
   It is the function to start normal navigation without any planned route.

3. “Start Routing..”
   It is the function to start navigation with planned route. The planned route will be shown to the users by center-lines (Figure 5.7).

4. “Reset..”
   It is the function to reset the map display. It is normally to be used after the use of any of the three functions stated above. Using any of the above three functions would result in changes in the attributes of the map contents. This function is designed to restore the original attributes of the map contents.

5. “End..”
   It is the function to terminate and quit the whole program.
Figure 5.6  New menu created to the map interface.

Figure 5.7  Mode of navigation with planned route.
The creation of the new menu was created using the program code as shown in Listing 5.1. For example, if the user chose “Start Normal”, the sub-program “StartSub” for navigation without planned route will be called to run. Similarly, choosing the menu in the new interface menu would call out the corresponding sub-program to run.

```
Create Menu “Demo” As
   “Restriction..” Calling Restriction,
   “Start Normal..” Calling StartSub,
   “Start Routing..” Calling StartRoute,
   “Reset..” Calling Reset,
   “End..” Calling EndSub
Alter Menu “Tools” Add
   “Demo” as “Demo”
```

Listing 5.1 Program code for the creation of new interface menu.

The restriction function was used to calculate and show the restricted area of road network according to the time schedule. In Hong Kong, the time schedule for restricted area is quite complex which has four categories:

- restricted from 0700 to 1900;
- restricted from 0700 to 0010 and from 1600 to 1900;
- restricted from 0700 to 2400 and
- 24 hours restricted.

It is a common problem that drivers find difficulties in recognizing the time schedule of restricted zone for their destinations. Road signs were not located sufficiently and in most cases were only located at start or end of the street. Drivers would have to refer to the mark on the road in order to get hints of the restricted time. If they found out the road has the possibility to be restricted, they had to wander around to find out the road sign which is located at unknown part of the street. Even
though they had found out the restricted time, they still had to refer to the clock and relate it to the time schedule to find out the answer. One may say that the whole process is very inconvenient and time-consuming, especially when the driver is not familiar with the road network. To tackle with this problem, a function for restricted zone was developed using MapBasic and the program code was shown in Listing 5.2. It reads the time from the computer and then simulate corresponding restricted zone of the road network in the map which was stored in different tables. A custom dialogue was created to tell the user the current time and corresponding restricted road will be shown in different color (Figure 5.8). In this way, much time and effort were saved and thus the driver can concentrate better on driving, resulted in increased efficiency and safety.
Sub Restriction()

Dim s_time as string
Dim temp_hour as string
Dim hour as float
s_time = Time(24)

hour = val(s_time)
Note "Current time is " + s_time + ".
Corresponding restricted road will be shown in orange."

if hour < 7 then
    Open Table "C:\restrict24" As restrict24
    Add Map Auto Layer restrict24
end if

if hour >= 7 And hour < 10 then
    Open Table "C:\\restrict0-7" As restrict7
    Add Map Auto Layer restrict7
end if

if hour >= 10 And hour < 16 then
    Open Table "C:\\restrict10-16" As restrict10
    Add Map Auto Layer restrict10
end if

if hour >=16 And hour < 19 then
    Open Table "C:\\restrict16-19" As restrict16
    Add Map Auto Layer restrict16
end if

if hour >=19 And hour < 24 then
    Open Table "C:\\restrict19-24" As restrict19
    Add Map Auto Layer restrict19
end if

End Sub

Listing 5.2 Program code of the function to calculate the restricted road area by time schedule.
Figure 5.8 Function to calculate the restricted road area by time schedule.

Interactivity was provided with the map. Different scale levels with different content levels and designs could be chosen by the users by zooming in and out. The program code for achieving the multi-scale representation was shown in Listing 5.3. The zoom extent (MapZoom in the Listing) was calculated by using the function “MapperInfo(MapWin_ID,MAPPER_INFO_SCALE)”. If the zoom extent was less than five, then the displayed scale was 1:2500. The corresponding layers “rdseed2”, “s2500” and “direction” for this scale were displayed. Similarly, if the zoom extent was equal to five, then the displayed scale was 1:5000. The corresponding layers “rdseed2”, “bldg_name” and “direction” for this scale were displayed. If the zoom extent was larger than five, then the displayed scale was 1:2500. The corresponding layers “rd20k”, “S10000” and “direction” for this scale were displayed. When the users zooms in/out, the map will change to the representable size of the chosen scale with the corresponding content levels which was done by calling different layers to be displayed. The map provided flexibility to the users to customize their use. Different
layers such as car park and restaurants locations can also be activated in the layers control (as shown in Figure 5.3) for different usages.

MapZoom = MapperInfo(MapWin_ID,MAPPER_INFO_SCALE)

    If MapZoom < 5 then
        ScaleType = 1
    else
        If MapZoom = 5 then
            ScaleType = 2
        else
            If MapZoom = 10 then
                ScaleType = 3
            End if
        End if
    End if

Do Case ScaleType

    Case 1

        TabName2 = "rdseed2"
        TabName3 = "S2500"
        TabName4 = "direction"

    Case 2

        TabName2 = "rdseed2"
        TabName3 = "bldg_name"
        TabName4 = "direction"

    Case 3

        TabName2 = "rd20k"
        TabName3 = "S10000"
        TabName4 = "direction"

End Case

Listing 5.3 Program code for the multi-scale representation.
Geographic objects manipulations were involved in the dynamic environment programming. To simulate the use of an in-vehicle positioning system, the program reads the vehicle’s position from a coordinate file, creates a car symbol and then displayed the car position on the map (Listing 5.4) with the car symbol. Display settings are controlled by centering the map window with the vehicle’s coordinates (Listing 5.5). The map window will be centered with the first set of coordinates of the vehicle. In this way, one of the exploratory acts, panning, could be passed over and operations from users could be saved by displaying the corresponding geographic area to them. However, the map window will not be redrawn every time when a new set of coordinates were read. Rather, the map window will be re-centered when the vehicle reached to one third of any side of it. This is because too much re-center of the map window might cause irritations to the drivers, as well as too much processing load to the system. Animation layer was added in order to increase the speed of redrawing the map when the vehicle moved (Listing 5.6). The animation layer is a feature extended by MapBasic, where the map redraws much more quickly if the objects being updated are stored in the animation layer instead of a conventional layer. With the application of the animation layer, the map window redraws very quickly when an object in the animation layer is moved even if the map is very complex (MapInfo Corporation, 1999).

```
'====== Open the coordinate file for input ======
Open File CoordLocat For Input As #1

'====== Store the coordinates ======
  x = FALSE
  do
    For i = 1 to 30000
      Next
      input #1, DDEx,DDEy
      Curr_X = DDEx
      Curr_Y = DDEy
      Call GpsPoint
      Old_X = DDEx
      Old_Y = DDEy
  Loop while Not EOF(1) and x = FALSE
```
Close File #1

' ========== Car Symbol ===========
tempSymbol = MakeCustomSymbol("targ1-32.bmp",RED,18,0)

' ========== init the Obj symbol in to anim_tbl ========== Create Point Into Variable tempObject (0,0) Symbol tempSymbol Insert Into Anim_Tbl( DispObjID, obj ) Values( i, tempObject)

Listing 5.4 Program code for the creation of car symbol by the coordinate file.

If IsPtInDisplayWin(currPoint) <> TRUE then
    Set Map Window gMapMainWinID Center (currPoint.x, currPoint.y )
End If

Listing 5.5 Program code for re-centering the map window.

' ========== Init the Display Object table ========== AnimTblName = "c:\anim.tab" If FileExists(AnimTblName)=TRUE Then
    Open Table AnimTblName as Anim_Tbl Drop Table Anim_Tbl End If

' ========== Create the Display Object table ======== Create Table Anim_Tbl ( DispObjID Integer) File AnimTblName Create Map For Anim_Tbl 'make the table mappable Set Table Anim_Tbl FastEdit On Undo Off

    gMapMainWinID = FrontWindow()

Add Map Window gMapMainWinID Layer Anim_Tbl Animate

Listing 5.6 Program code for the creation of animation layer.
5.4 Assignment of Highlighting Effect for Individual Map Content

In order to select map contents in close proximity of the vehicle and assign different prominences to them, a buffer zone was created with the car position (Listing 5.7) using a circle with a radius of 10 metres.

```vbnet
Dim SmallCircle as Object
SmallCircle = CreateCircle(currPoint.X, currPoint.Y, 10)
```

Listing 5.7 Program code for the creation of small buffer zone.

The buffer zone SmallCircle was used to select features in the immediate neighbourhood of the vehicle and to assign highlighting effect to them. Those selected features would then be assigned different attributes to provide a dynamic highlighted effect, e.g. increase in size, increase in thickness, contrasting color and flashing effect. The use of dynamic variables and visual variables were combined in order to emphasize the prominences. The identity (ID) of the selected feature as well as its attributes will be stored in an array of the database. Then new attributes will be assigned to the feature in order to produce the highlighting effect.

However, new buffer zone will be created with the new position when the vehicle moves. Then the feature that was selected before would undergo a point-in-polygon calculation to test whether it was inside or outside the new buffer zone. If the feature were inside the new buffer zone, it would keep with the new attributes until it was calculated to be outside another new buffer zone. When the feature was outside the buffer zone, its ID will be recalled to retrieve back to its original attributes which was stored in the array. The use of this buffer zone has the advantage that only those features around the vehicle would be highlighted while all the others were provided with a faded out effect. As shown in Figure 5.9, the road name “Harbour Rd” was originally colored in a light grey value (circled in orange in the figure). The light grey value aims at providing the viewer with a faded out effect such that
attention would not be directed to it. When the road name fell into the buffer zone (which was the pink circle), the road name was enlarged and highlighted with a red color. Also, the road segments which fell in the buffer zone was colored in blue.

![Map with features highlighted by small buffer zone](image)

Figure 5.9  Features highlighted by small buffer zone.

Listing 5.8 shows the program code for selecting road names in the "road_name" layer. Any selected road names would be and stored in the table "Query_tab" as temporary objects in different rows. The font style and font color would be queried and stored for restoration in latter stage. Then the road names would be assigned with new attributes in order to produce the highlighting effect. In this example, the highlighting effect was done by enlarging the name's size and changing the font color into red. The name's size was enlarged by changing the maximum x and y coordinates of the minimum bounding rectangle which defines the size of the font object. The font color was changed by the command "MakeFont (fontname, style, size, forecolor, backcolor)". Once any of the selected road names was out of the buffer zone defined by the new vehicle position, the corresponding temporary objects would be called out from the "Query_tab" for restoring the original
attributes of the road names. The corresponding row in the Query_tab was linked by the road name’s ID.

```
Set TABLE road_name USEREDIT ON

Select * From road_name where road_name.obj partly within BufferCircle
    into Query_tab

'===== The part of checking the color of the original text object =====
FontStyle = ObjectInfo (road_name.obj, OBJ_INFO_TEXTFONT)
FontColor = StyleAttr (FontStyle, FONT_FORECOLOR)
Row_No = TableInfo (Query_tab, TAB_INFO_NROWS)

For i = 1 to Row_no
    Update Query_tab set Obj = Temp_Obj where rowid = i
    query.id(i) = query_tab.id

    NewFont = MakeFont("Arial", 0, 24, RED,-1)
    Fetch rec i From Query_tab
    Temp_Obj = Query_tab.obj

    Alter Object Temp_Obj Geography OBJ_GEO_MAXX,
        (ObjectGeography(Temp_Obj, OBJ_GEO_MAXX)+30)
    Alter Object Temp_Obj Geography OBJ_GEO_MAXY,
        (ObjectGeography(Temp_Obj, OBJ_GEO_MAXY)+30)
    Alter Object Temp_Obj info OBJ_INFO_TEXTFONT, NewFont

Next
```

Listing 5.8  Program code for the highlighting effect of road names.

In the previous example, the highlighting effect was done by increasing the font size and changing the font color into a sharper one. Another way to achieve it was done by the highlighting effect. Since MapInfo Professional and MapBasic do not have any built in function for it, the flashing effect had to be created. It was done by covering the selected symbol with a solid rectangle in fixed time interval. Figure 5.10a shows an example of a symbol to be assigned with the flashing effect, in which
the dashed line shows the symbol's minimum bounding rectangle. A solid rectangle with the same size as the symbol's minimum bounding rectangle was created (Figure 5.10b) and it was termed as the cover symbol. It was filled with light yellow which is the same color as the background color of road segments. The two symbols will be called out for display in alternative time intervals in order to create the flashing effect and Listing 5.9 shows the sub-program for achieving that. At the beginning of the sub-program, three parameters would be passed from the main program to the sub-program. The first parameter was the row number of the table which stored the symbol which was going to be assigned with the flashing effect. The second one was the attributes of the symbol ("CurrSymbol") and the third one was a temporary object for the flashing effect. A "CoverSymbol" was created which was the same as the one shown in Figure 5.10b. The "CurrSymbol" and the "CoverSymbol" would be called out for display in alternative case, i.e. alternative time interval. In odd case number, "CurrSymbol" was called out and the user would see the symbol. While in even case number, "CoverSymbol" was called out and since it was created with the same color as the background color of road segments, it appeared as a transparent object such that the user would have a perception that the symbol has disappeared. By looping between the odd and even numbers of cases, the symbol appeared and disappeared and thus the flashing effect was created.

![Image](image.png)

(a) (b)

Figure 5.10 Symbols for the creation of flashing effect.
Sub FlashSymbol (row_no as integer, CurrSymbol as Symbol, FlashObj as Object)

    Dim i,j as integer
    Dim CoverSymbol as Symbol

    CoverSymbol = MakeCustomSymbol ("Cover.bmp", yellow, 36,0)
    for i = 1 to 11

    Do Case i

    Case 1,3,5,7,9,11
        Alter Object FlashObj
        info OBJ_INFO_SYMBOL, CoverSymbol
    Case 2,4,6,8,10
        Alter Object FlashObj
        info OBJ_INFO_SYMBOL, CurrSymbol

    End Case

    Update Query_tab set Obj = FlashObj where rowid = row_no

    For j = 1 to 4000
        Next

    Next

End Sub

Listing 5.9    Sub-program for creating the flashing effect.

5.5    Assignment of Highlighting Effect in the Central Display Area

   In the previous session, the assignment of increase prominence for individual map content was discussed. Apart from this, another way to achieve better perception could be done by highlighting the central display area (Figure 5.10). In Listing 5.10, a buffer zone was created by a circle with a radius of 250 metres using similar program codes as in Listing 5.7. It was used to highlight the roads in the central part of the displayed area around the vehicle for easier perception for the users. "NewGround" was the color used to highlight the road segments, which was light
purple as shown in Figure 5.11. "BKGD" was the layer which stored the color polygons for furnishing the road segments as mentioned in session 5.2. Any color polygon which fell within the buffer zone "BigCircle" defined by the vehicle position would be selected. It was then assigned with the color "NewGround" in order to create the highlighting effect. The retrieval of the original color of the road segments after the vehicle moved to another position was done by similar method as discussed in the previous session.

Figure 5.11  Road segments highlighted by large buffer zone (circled in orange)
Dim BigCircle as Object

BigCircle = CreateCircle(currPoint.X, currPoint.Y, 250)

'==== Change the color of polygon inside the buffer zone "BigCircle" ====
NewGround = MakeBrush(2, RGB(232, 208, 255), -1)

Select * From BKGD where bkgd.obj within BigCircle into Query_tab
Row_No = TableInfo(Query_tab, TAB_INFO_NROWS)

For i = 1 to Row_No

    Fetch rec i From Query_tab

    If Query_tab.id < 1000 then
        Temp_Obj = Query_tab.obj
        Alter Object Temp_Obj
        info OBJ_INFO_BRUSH, NewGround
        Update Query_tab set Obj = Temp_Obj where rowid = i
    End if

    query.Bigid(i) = query_tab.id

Next

Listing 5.10 Program code for the assignment of increased prominence in the central display area.
CHAPTER 6

EXPERIMENTAL EVALUATION

6.1 Design of Experimental Testing on Navigation Maps

As mentioned in Chapter 3, factors to be considered in the design of dynamic maps for vehicle navigation include visual variables, dynamic variables, exploratory acts and map complexity. A series of maps were produced that contained various combinations of cartographic elements. This Chapter describes a set of three experiments that were constructed to evaluate the effectiveness of the alternative designs.

For navigation maps, the most important content was the road network. Therefore, it is imperative that the first thing to be evaluated is its representation. A road network could be shown either by center-lines or by both sides of the roads. It was quite clear that center-lines should be used for scale level 1:10000 and both sides of the roads should be used for scale level 1:2500. However, what representation should be used for the working scale level 1:5000 still remained vague. The first experiment was to establish the preferred representation of a road network for the working scale level.

The second experiment concentrated on the effectiveness of change of map contents’ prominences according to the vehicle position. Different visual variables and dynamic variables could be used in order to achieve this. Thus, one has to evaluate which visual variables and/or dynamic variables should be used for different map contents effectively. Since dynamic effect by varied prominences would not be assigned to the scale level 1:10000, experiments would only be carried out for the scale levels 1:2500 and 1:5000.

The third experiment focused on variations in other network related elements such as road names, symbols and the planned route which were also important map contents for vehicle navigation. Static visual variables include size, shape, orientation
and color. For static visual variables to be applied to road names, size should not be evaluated since it would be changed by the dynamic effect. Also, shape should not be evaluated since it was not applicable to text symbols. Thus, only orientation and color should be evaluated for road names. Apart from the text symbols, there were two more key symbols contained in the map, which were landmark symbol and direction restriction symbol. They should be evaluated by their complexities since their representation would be quite complex and not possible to be evaluated by individual visual variable. Different designs of the two symbols would be made with different map complexities and to be evaluated by the users. For the planned route, its orientation would be controlled by the defined coordinates. It would be presented by center-lines of the road network in order to increase clarity of the map and thus the shape and size were also controlled. Therefore, the visual variable which should be evaluated was color.

In order to evaluate the representation of map contents, three main experiments with the map complexity test suggested by MacEachren (1982) were carried out, in which subjects were asked to record the perceived map complexity on different designs of map. As a summary, the first experiment aims at finding the suitable expression grade, i.e. the complexity, of road network at the working scale. The second experiment aims at finding the suitable highlighting effect for different map contents in order to assign different prominences to them according to the vehicle position. Highlighting effect by different use of visual and dynamic variables were performed and evaluated. The third experiment aims at finding the most effective design for symbols, road names and the planned route by the effective use of visual variables. Different designs were created for evaluation. In all of the three experiments, the design which obtained the least perceived map complexity was believed to be the most effective one.

In order to confirm the results obtained in the three experiments, a viewing time record was produced. It recorded the length of time the map was viewed to answer the questions correctly for each subject. This recording to be done after the three experiments allows familiarization for the users with the maps such that it won't affect the viewing time results. Several sets of maps using different design of map contents being tested in the three experiments would be produced. The following
questions were asked and the viewing time using different sets of maps for the subjects to answer the questions correctly was recorded.

**Questions:**

1. *Can you locate the vehicle on the map?*
2. *Can you state the road name where the vehicle is navigating in?*
3. *Can you locate the district where the vehicle is in?*
4. *Can you locate the way the vehicle is going to navigate?*
5. *Can you locate and state the name of any building near the vehicle?*

Each design of map was presented and the same set of questions that stated above was asked. The time used by the respondents for finding out the answers was recorded. The one with the least responding time required to answer the questions correctly was believed to be more effective. After that, the results obtained from the three experiments could be compared with the results obtained in the viewing time record. If the two results agreed with each other, they could be considered as reliable. Several effective criteria could be obtained from the two results and a set of "improved" maps was produced by using them.

Visual variables, dynamic variables and map complexity which concerned about the representation of map contents would be evaluated in the first three experiments. Lastly, the exploratory acts employed in the dynamic maps should be assessed, which was related to the functions developed. Evaluation of the functions developed would be done in the fourth experiment. Functions developed includes the use of buffer zone to highlight features in close proximity of the vehicle, the use of buffer zone to highlight road segments in the central display area, the multi-scale representation and the presentation of restricted roads. Respondents would be asked to comment on the helpfulness of the functions in perceiving the map.

After all the factors were evaluated in different representations, the map was evaluated according to the overall design which was an important procedure in any map design process. The map would be presented to the respondents to undergo a map evaluation process according to the guidelines suggested by Dent (1993). If the
map received positive comments from respondents in the evaluation, the design of the map was believed to be an effective one.

All the experiments and evaluations in this study would be carried out in a simulated environment. Real GPS data collected beforehand was used in order to simulate the use of an in-vehicle positioning system. One may argue that the experiments and evaluations should be conducted in a real driving environment, i.e. test the maps in a moving vehicle, so that they could be evaluated in a situation akin to how they may be used upon implementation. There were three key reasons why this was not done. First and foremost one concerns about the objective of this study. This study emphasizes on the cartographic design of dynamic multi-scale maps applied to land vehicle navigation. The integration of GPS positioning system into the map display system is not the major investigation focus. Secondly, the availability of a vehicle and in-car navigation systems that could be interfaced to the map system upon which this work was based. Expensive equipments such as a vehicle and a GPS receiver had to be involved. Also, some specialized techniques such as map-matching and dead reckoning had to be applied. Moreover, an interface between the dynamic map and the GPS system had to be developed. If the map were to be evaluated in a real driving environment, the cost and manpower required would be increased dramatically, which might not be possible for this project. The third reason was related to finding appropriate subjects with driving licenses. Unlike western countries, Hong Kong has a comprehensive public transport system and a high cost of car ownership meaning that very few people have driving licenses. Finding a statistically significant sample of people willing to take the risk of driving and evaluating was extremely difficult. It is recognized that the subsequent simulated mode evaluation is a limitation of the validity of the outcomes, but for those stated very practical reasons, the limitation were accepted.

Subjects for the experiments were chosen who fulfilled the dichotomous attributes of novice/expert and male/female with equal proportions of each of these subgroups included in two test groups. In this study novices refer to those individuals whose knowledge of maps and their map-reading experience are at beginners’ level, while experts refer to those individuals with much map-reading experience or have been trained in cartography. Novices and experts were needed to determine whether
knowledge and/or level of experience influenced the way subjects interact with and perceive information from the map. In total, results from 60 subjects were analyzed.

Although this study was not designed to test gender variation in map use initially, the opportunity to collect data by gender was presented. However, there was no significant variation in responses between male users and female map users in this study. This agreed with the results from studies by Gilmartin (1986) and Gilmartin and Patton (1984). One may argue that there may be gender variation in spatial abilities. However, in practice this variation does not carry over to how maps are used or the results of decisions based on maps.

6.2 Experiment 1: Representation of Road Network at the Working Scale

This experiment aims at finding out the suitable expression grade of road network at the working scale, i.e. 1:5000. The effective complexity of road network was to be sought. Road network can be shown with both sides of road, with centerlines of road or even both of the above. It is quite obvious that centre-lines should be shown for the roads in scale level 1:10000 while both sides of the roads should be shown in scale level 1:2500. However, it is rather ambiguous to decide which one to be shown in the working scale level, 1:5000. Therefore, three sets of maps with these three representations were shown to the subjects to undergo the map complexity test suggested by MacEachren (1982).
Table 6.1  Results about representation of road network at the working scale.

<table>
<thead>
<tr>
<th>Types of representation of road network at the working scale.</th>
<th>Perceived map complexity</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Results from novices</td>
<td>μ</td>
<td>δ</td>
<td>μ</td>
</tr>
<tr>
<td>1) Shown with center-lines of roads</td>
<td>4.4</td>
<td>1.05</td>
<td>3.8</td>
<td>0.97</td>
</tr>
<tr>
<td>2) Shown with both sides of roads</td>
<td>2.5</td>
<td>0.79</td>
<td>3.5</td>
<td>0.77</td>
</tr>
<tr>
<td>3) Shown with both of the above</td>
<td>7.9</td>
<td>1.35</td>
<td>9.4</td>
<td>1.16</td>
</tr>
</tbody>
</table>

According to the overall response from the subjects (Table 6.1), road network with both sides shown is better for the working scale since lower map complexity was perceived. Road network with both sides shown received the lowest perceived map complexity, while that with both sides and center-lines shown together received the highest value. Feedback from subjects claimed that road network shown in both representations was too chaotic and difficult to distinguish the two. It didn’t help them in perceiving the maps. Rather, it was considered as noise and made their perception much difficult. Therefore, the perceived map complexity of this presentation was much higher than the other two.

Both novices and experts perceived lower map complexity for the road network with both sides shown. However, one could see that there is considerable difference between the response from novices and experts. The standardized geometric mean of map complexity for center-lines of roads from experts was 3.8, while that for roads with both sides shown was 3.5. There was no significant difference between the two results. Compared to that from experts, novices perceived a mean value of 4.4 for the former case and 2.5 for the latter case. There were considerable differences. Opinion from novices claimed that most of the street maps or driving guides available in the market seldom use centre-lines to represent the road network and thus they were not used to it. Although road network shown in center-lines was geometrically simpler, it was difficult for the novices to understand the map.

---

1 Standardized geometric mean  
2 Standard deviation
leading to higher perceived map complexity. Since most of the users won't be experts, it is suggested that to represent road network with both sides shown in the navigation map. One can see that the standard deviations of all the results were similar to each other with values around one, showing that the results were reliable.

In the viewing time record, the map shown with road network by both sides of the roads received the fastest respond time from the respondents, while the map with shown with center-lines received the slowest respond time. Therefore, it can be concluded that the viewing time record agreed with the perceived map complexity test and the results were believed to be reliable.

6.3 Experiment 2: Change of Map Contents Prominence According to the Vehicle Position

As mentioned in Chapter 5, buffer zones generated by the vehicle's position will be used to create the dynamic effect. A buffer zone was used to select features in close proximity of the vehicle, and highlighting effect will be assigned to those selected features in order to allow easier perception for users. Several ways could be used by varying the features' attributes in order to achieve this. Features' attributes could be varied by varying the visual and dynamic variables. This experiment aims at finding out the most effective way to create the highlighting effect for different features by varying the visual and dynamic variables using the map complexity test suggested by MacEachren in 1982. The highlighting effect could be achieved by altering the size or color of the features or by applying a flashing effect. Features included road segments, building names, road names and direction restriction symbols. Since highlighting effect would only be carried out in scale level 1:2500 and 1:5000, experiments were done with these two levels. In this experiment, no significant difference was observed from the results between novices and experts. Thus, mean value calculated from novices and experts were shown rather than individual ones.
From Table 6.2, one can see that highlighting effect for road segments done by changing their color in scale level 1:2500 obtained the lowest perceived map complexity with a value of 4.7, while that done by enlarging size and flashing effect were 8.8 and 10.1 respectively. The value was comparatively much lower than the other two and similar case was observed with scale level 1:5000. Also, the standard deviations calculated were lower than the value of one, showing that the results were reliable. Therefore, there was no doubt that road segments should be highlighted by changing the segments' color for both of the scale levels.

Building names and road names obtained similar results for the three highlighting effects in the two scale levels, which ranged from 4.4 to 6.3. The effect produced by changing features' color provided the lowest perceived map complexity, while that by flashing provided the highest value and that by enlarging size gave results between the two. All the three effects were proved to be effective for easier perception to users. However, results obtained from the three effects didn’t show great differences from each other. None of them provided outstanding result which is persuasive to stand alone to become the best method.

Direction restriction symbols highlighted by enlarging size gave a value of 4.1 in scale level 1:2500 and a value of 4.4 in scale level 1:5000. When they were highlighted by flashing effect, values of 4.1 and 3.5 were obtained in scale level 1:2500 and 1:5000 respectively. The standard deviations for the two highlighting effect obtained values around one for both of the scale, showing that the results were reliable. Compared with the two effects stated above, changing color to highlight the direction restriction symbols got higher values (which was 5.7 and 5.8) for the two scale levels. That is, direction restriction symbols highlighted by enlarging size and as well as using flashing effect obtained lower complexity when compared with that by changing color.

From the above, one may conclude that flashing effect is effective for all the features except 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 on the most effective one, i.e. the direction restriction symbol. As a summary, road segments were highlighted by changing the color. Building
names and road names were highlighted by changing the color and increasing the font size. Direction restriction symbols were highlighted by increasing in size plus flashing effect. All are applicable to both of the scale levels 1:2500 and 1:5000.

The different highlighting effects were also evaluated by the viewing time record. Shorter viewing time was recorded for the maps produced by those criteria which had been proven for their effectiveness in the perceived map complexity test when compared with the maps produced by their counterparts. Therefore, it can be concluded that the viewing time record agreed with the perceived map complexity test and the results were believed to be reliable.

Table 6.2 Highlighting effect by varying visual and dynamic variables.

<table>
<thead>
<tr>
<th>Highlighting effect</th>
<th>Perceived map complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scale level 1:2500</td>
</tr>
<tr>
<td></td>
<td>( \mu )</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>1) Enlarging size in order to highlight:</td>
<td></td>
</tr>
<tr>
<td>a) road segments</td>
<td>8.8</td>
</tr>
<tr>
<td>b) building names</td>
<td>5.5</td>
</tr>
<tr>
<td>c) road names</td>
<td>5.1</td>
</tr>
<tr>
<td>d) direction restriction symbols</td>
<td>4.1</td>
</tr>
<tr>
<td>2) Changing color in order to highlight:</td>
<td></td>
</tr>
<tr>
<td>a) road segments</td>
<td>4.7</td>
</tr>
<tr>
<td>b) building names</td>
<td>4.9</td>
</tr>
<tr>
<td>c) road names</td>
<td>4.5</td>
</tr>
<tr>
<td>d) direction restriction symbols</td>
<td>5.7</td>
</tr>
<tr>
<td>3) Using flashing effect in order to highlight:</td>
<td></td>
</tr>
<tr>
<td>a) road segments</td>
<td>10.1</td>
</tr>
<tr>
<td>b) building names</td>
<td>5.9</td>
</tr>
<tr>
<td>c) road names</td>
<td>5.5</td>
</tr>
<tr>
<td>d) direction restriction symbols</td>
<td>4.1</td>
</tr>
</tbody>
</table>
6.4 **Experiment 3: Design of Symbols, Road Names and Planned Route**

This experiment aims at finding out the most effective design for symbols, road names and the planned route with the consideration of visual variables. Same method as experiment 2 was used, i.e. by the map complexity test suggested by MacEachren in 1982. In this experiment, no significant difference was observed from the results between novices and experts. Therefore, mean value calculated from novices and experts were shown rather than individual ones.

The first thing to be considered was the design of the road names presentations. Color of road names as well as the orientations were considered in this experiment. From Table 4.1 & 4.2, it can be seen that the road names were assigned with a light grey color to provide a faded out effect. This was aimed to decrease the map complexity and thus was tested for its effectiveness in the experiment. From Table 6.3, one can see that the perceived map complexities were 4.5 and 3.9 for scale levels 1:2500 and 1:5000 respectively. They were both lower than the results provided by the maps without the faded out effect for the road names in the two scale levels. Also, the standard deviation calculated were lower than one, showing that the results were reliable. Therefore, it can be concluded that the road names assigned with a faded out color was effectively for decreasing the perceived map complexity.

As shown in Table 6.3, north-up orientations of road names obtained lower value for the scale level 1:5000 and lower standard deviation when compared to its counterpart which oriented road names according to the rotation angle of the road segments. Opinions from respondents stated that road names orientated with different angles were difficult to perceive and made the maps more complex. The names were more difficult to read especially when they were orientated vertically. However, the north-up orientation of road names was not so beneficial when it was applied in scale level 1:2500. Subjects claimed that there were much more contents contained in that scale level. When the road names were orientated in a north-up manner, it would occupy much more space and thus made the map more complex. Therefore, it can be concluded that north-up orientation of road names provided better and easier
perception for the scale level 1:5000, while road names orientated according to the rotation angles of road segments would be better for scale level 1:2500.

In the viewing time record, respondents spent less time to answer the questions correctly when the road names were assigned with the faded out effect for both of the scale levels. For the orientation of road names, respondents spent less time to answer correctly when the road names were orientated in a north-up manner in the working scale level 1:5000. However, it took longer time for them to respond when the road names were orientated in a north-up manner in the scale level 1:2500. Therefore, it could be concluded that the viewing time record agreed with the perceived map complexity test and the results were believed to be reliable.

Table 6.3  Design of road name presentation.

<table>
<thead>
<tr>
<th>Road name presentation</th>
<th>Perceived map complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scale level 1:2500</td>
</tr>
<tr>
<td></td>
<td>μ</td>
</tr>
<tr>
<td>1)  Color of road names:</td>
<td></td>
</tr>
<tr>
<td>a) With faded out effect (light grey color)</td>
<td>4.5</td>
</tr>
<tr>
<td>b) Without faded out effect</td>
<td>7.0</td>
</tr>
<tr>
<td>2)  Orientation of road names:</td>
<td></td>
</tr>
<tr>
<td>a) North-up</td>
<td>7.0</td>
</tr>
<tr>
<td>b) According to the rotation angle of the road segments.</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Secondly, it came to the design of symbols presentation. For the direction restriction symbol, two designed were made. One was aimed to replicate the symbol used in the road signs developed by the Transport Department (Figure 6.1), where the other one was a simplified version of the former one (Figure 6.2). The simplified version only used black and white color, and the outside border of the original symbol
was omitted. From Table 6.4, it was shown that the original symbol obtained perceived map complexities which were lower than that obtained by the simplified version with values of 1.4 and 1.3 for scale level 1:2500 and 1:5000 correspondingly. Also, the standard deviations obtained were lower with values of 0.85 and 0.86 for scale level 1:2500 and 1:5000 respectively. Although the simplified version was geographically simpler, the perceived map complexity was higher. It showed that the original version was easier for the users to relate to the symbols employed in the road signs that they’ve already used to, leading to lower perceived map complexity. Moreover, presentation of landmark by perspective icons received lower perceived map complexity for both of the scale levels, implying it allowed easier perception for the users.

Lastly, the design of the planned route was investigated. From previous experiment, it was shown that road network is better to be highlighted by change of color from the above experiment. Therefore, one may say that this would also be applicable to the planned route, which is a kind of road network in the form of road center-lines. The next thing to evaluate is to determine how should the planned route’s color be changed. In fact, planned route could be broken into three parts according to the vehicle’s position which are (i) the part of planned route that the vehicle is going to navigated; (ii) the part of planned route that the vehicle is navigating in, which can be defined by the use of a buffer zone; (iii) the part of planned route that the vehicle has already navigated. Another alternative of not assigning any color to the planned route was also included in the experiment in order to confirm that changing color is also effective for the planned route for better perception. From Table 6.5, one can see that assigning color to the planned route obtained lower perceived map complexity for both of the scale levels and thus it was proved to be effective for better perception. Moreover, results suggested that the planned route should be changed with three colors, applying to the part of route that the vehicle is navigating, going to navigate and to the part that the vehicle has already navigated. The standard deviations calculated obtained values around one, showing that the results were reliable.

In the viewing time record, shorter viewing time was recorded for the maps produced by direction restriction symbols replicating the road signs produced by the
Transport Department and by the perspective landmarks. Also shorter viewing time was recorded for the maps with planned route presented with three colors, applying to the part of route that the vehicle is navigating, going to navigate and to the part that the vehicle has already navigated. Therefore, it can be concluded that the viewing time record agreed with the perceived map complexity test and the results were believed to be reliable.

<table>
<thead>
<tr>
<th>Symbol presentation</th>
<th>Perceived map complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scale level 1:2500</td>
</tr>
<tr>
<td></td>
<td>μ</td>
</tr>
<tr>
<td>1) Presentation of direction restriction symbols.</td>
<td>4.3</td>
</tr>
<tr>
<td>a) Replicate the road signs produced by Transport Department.</td>
<td>5.7</td>
</tr>
<tr>
<td>b) Simplified versions of the road signs produced by Transport Department.</td>
<td></td>
</tr>
<tr>
<td>2) Presentation of landmarks:</td>
<td>6.3</td>
</tr>
<tr>
<td>a) By names of landmarks</td>
<td>4.4</td>
</tr>
</tbody>
</table>
Table 6.5    Design of planned route presentation.

<table>
<thead>
<tr>
<th>Planned route presentation</th>
<th>Perceived map complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1). Assigning two different colors to the respective parts of planned route according to the vehicle’s position. ³</td>
<td>5.1                      0.95  4.8  0.87</td>
</tr>
<tr>
<td>2). Assigning three different colors to the respective parts of planned route according to the vehicle’s position. ⁴</td>
<td>4.3                      0.99  4.0  1.03</td>
</tr>
<tr>
<td>3). Without assigning any color to the planned route.</td>
<td>6.3                      1.09  5.8  0.73</td>
</tr>
</tbody>
</table>

³ The planned route was broken into two different parts: (i) part of route that the vehicle has already navigated and (ii) part of route that the vehicle is going to navigate.

⁴ The planned route was broken into three different parts: (i) part of route that the vehicle has already navigated; (ii) part of route that the vehicle is navigating in; and (iii) part of route that the vehicle is going to navigate.
6.5 Experiment 4: Evaluation of Functions Developed

This experiment aims at evaluating the functions developed in this study and the results were shown in Table 6.6. Functions included the use of buffer zones to create the dynamic effect for different scale levels, the presentation of restricted roads which based on calculation of time schedule and the multi-scale levels representation in which classification were shown in different layers in different scale levels. Subjects were asked to give their opinions about the system’s functions on a scale from one to seven, with one representing “very helpful” and seven representing “not at all helpful”.

In this study, there was no significant difference between the results from novices and experts. All the standard deviations calculated obtained values not greater than 1.05, showing that the results were reliable. The use of 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. However, it was not helpful for scale level 1:10000. One can also see that the use of buffer zone for the highlighting effect is more effective in maps without planned route when compared with the one with planned route. The use of a buffer zone to highlight the road segments in the central display area around the vehicle also showed helpfulness in perceiving the map in the working scale 1:5000 when the vehicle navigated without a planned route. On the other hand, it was not helpful when the vehicle navigated with a planned route. One of the reasons would be that the users’ attention was focused to the planned route and thus road area highlighted by another color would be considered to be complex to the users. For scale level 1:2500, the use of the buffer zone was not useful no matter with or without planned route. It might be because this scale level was constructed with a higher content levels. Adding extra attributes to the road area would again be considered as being more complex. Lastly, the use of multi-scale representation and the presentation of restricted roads according to time schedule also proved their helpfulness in perceiving the map. The value got by the presentation of restricted roads was persuading, with a value of 1.3 which can be said to be very helpful.
<table>
<thead>
<tr>
<th>Feature Description</th>
<th>Response</th>
<th>μ</th>
<th>δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Having the buffer zone to highlight features in close neighbourhood of the vehicle when the vehicle navigates without planned route in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) scale level 1:2500</td>
<td></td>
<td>2.8</td>
<td>1.05</td>
</tr>
<tr>
<td>(b) scale level 1:5000</td>
<td></td>
<td>2.1</td>
<td>0.84</td>
</tr>
<tr>
<td>(c) scale level 1:10000</td>
<td></td>
<td>5.7</td>
<td>0.96</td>
</tr>
<tr>
<td>Having the buffer zone to highlight features in close neighbourhood of the vehicle when the vehicle navigates with planned route in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) scale level 1:2500</td>
<td></td>
<td>3.1</td>
<td>0.93</td>
</tr>
<tr>
<td>(b) scale level 1:5000</td>
<td></td>
<td>2.7</td>
<td>0.97</td>
</tr>
<tr>
<td>(c) scale level 1:10000</td>
<td></td>
<td>5.5</td>
<td>1.01</td>
</tr>
<tr>
<td>Having the buffer zone to highlight the road segments in the central display area around the vehicle when the vehicle navigates without planned route in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) scale level 1:2500</td>
<td></td>
<td>4.7</td>
<td>0.97</td>
</tr>
<tr>
<td>(b) scale level 1:5000</td>
<td></td>
<td>2.5</td>
<td>0.90</td>
</tr>
<tr>
<td>Having the buffer zone to highlight the road segments in the central display area around the vehicle when the vehicle navigates with planned route in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) scale level 1:2500</td>
<td></td>
<td>5.9</td>
<td>0.80</td>
</tr>
<tr>
<td>(b) scale level 1:5000</td>
<td></td>
<td>4.6</td>
<td>0.91</td>
</tr>
<tr>
<td>The multi-scale representation.</td>
<td></td>
<td>2.8</td>
<td>0.88</td>
</tr>
<tr>
<td>The presentation of restricted roads.</td>
<td></td>
<td>1.3</td>
<td>0.54</td>
</tr>
</tbody>
</table>
6.6 Experiment 5: Evaluation of the Overall Map Design

According to the guidelines to assist map evaluation produced by Dent (1993), subjects were asked to comment the different design of the maps. Each aspect of the guidelines were taken into account.

1. *A map should be suited to the needs of its users.*
   Since the map is aided for navigation, the main concern is that whether the map can guide the users to the destination. Other concerns include recognition of the area the user was in, sufficiency of information such as locations of car park etc.

2. *A map should be easy to use.*
   Subjects were asked whether they could handle to use the map easily without the help of the others. Moreover, the ease of understanding of the wordings used in the system would also be a concern.

3. *Maps should be accurate, presenting information without error, distortion, or misinterpretation.*
   Subjects were asked to report any inaccurate information portrayed by the system.

4. *The language of the map should be related to the elements or qualities represented.*
   Symbol is the language of cartographic communication (Leung, 1999). Symbols used in the system were evaluated by the users with respect to the design and appropriateness.

5. *A map should be clear, legible, and attractive.*

6. *Many maps would ideally permit interaction with the user, allowing change, updating, or personalization.*
A map was produced by those previously established effective criteria and underwent the map evaluation process of Dent (1993). Subjects were asked to comment on the design of the map.

<table>
<thead>
<tr>
<th>Please comment on the following criteria using the range of 1 (strongly agree) to 7 (strongly disagree)</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>μ</td>
</tr>
<tr>
<td>1. The map suits your needs (assuming in navigation use).</td>
<td>3.1</td>
</tr>
<tr>
<td>2. The map is easy to use.</td>
<td>2.1</td>
</tr>
<tr>
<td>3. The map is accurate, presenting information without error, distortion, or misinterpretation.</td>
<td>N/A</td>
</tr>
<tr>
<td>4. The language of the map relates to the elements or qualities represented.</td>
<td>2.9</td>
</tr>
<tr>
<td>5. The map is clear, legible, and attractive.</td>
<td>3.6</td>
</tr>
<tr>
<td>6. The map permits interaction with you, allowing change, updating, or personalization.</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Criterion 3 was withdrawn because subjects claimed that they didn’t know how to define “accurate” and there was no “accurate” map for them to compare with. Apart from this, the remaining five criteria have gained positive comments from subjects and with standard deviations not greater than the value of one. Thus, the map evaluation process was put to an end.
CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

7.1 Summary

This project aims at investigating the effective cartographic design of dynamic multi-scale maps for land vehicle navigation. In this study, a set of dynamic maps with multi-scale representation was produced, which was consisted of scale levels 1:2500, 1:5000 and 1:10000. Drivers were provided with the choice of navigating with or without planned route. Contents levels and their representations differed for each scale. The road network was generalized into different extent for different scale level according to the road classification. Different contents were put into different layers such that different scale could stimulate different contents by zooming in and out. Dynamic effects were produced by the use of two buffer zones created with the vehicle’s position. When the vehicles moves, one small and one large buffer zones were created. The small buffer zone was used to select features which were in immediate neighbourhood of the vehicles in order to highlight the features by changing their attributes. Different highlight effects were tried by varying the visual variables and dynamic variables. All other features were provided with a faded out effect to decrease the map complexity. For example, road names were assigned with a light grey color while direction restriction symbols were assigned with a relative small size. The large buffer zone was used to highlight the road area in the central region for better perception. In this way, the prominence of each content would not be constant. Rather, it differs according to the vehicle’s position.

Several sets of maps were designed and then underwent map evaluations. Sixty subjects were chosen who fulfilled the dichotomous attributes of novice/expert and male/female with equal proportions of each of these subgroups. Map complexity tests suggested by MacEachren (1982) were first carried out to find out the effective ways for presenting the map contents. The results were then confirmed by viewing time records.
The effectiveness of using the buffer zones to create dynamic effect, the multiscale presentation and the function for calculating the restricted road area were then assessed. Finally, the map functions developed in this study as well as the map design were evaluated.

7.2 Conclusions

For scale level 1:5000, it was found that road network should be shown with both sides of the roads since it received the lowest overall perceived map complexity with the value of 3.0 by the respondents, while the values for others are from 3.8 to 9.4 (Table 6.1). Both small buffer zone to highlight features in close neighbourhood of the vehicle and large buffer zone to highlight the road segments in the central display area around the vehicle contributed in the increase in effectiveness of map perception. For scale level 1:2500, road network shown was the same as scale level 1:5000. Only small buffer zone to highlight features in close proximity of the vehicle was helpful in perceiving the map. For scale level 1:10000, only center-lines of road network were shown and the use of buffer zone to highlight features was not helpful in this scale level.

Different highlighting techniques by the use of small buffer zone were presented and tested for effectiveness for scale levels 1:2500 and 1:5000. Experiments for the two scale levels showed similar results. Highlighting technique which received the lowest perceived map complexity was employed. From the results, it showed that road segments should be highlighted by changing the color, building names and road names should be highlighted by changing the color and increasing the font size, and direction restriction symbols should be highlighted by increasing in size plus flashing effect.

For orientations of road names, results from Table 6.3 showed that different orientations should be used for different scale levels. For scale 1:2500, road names orientated according to the rotation angle of the road segments received a value of 5.1 for the perceived map complexity while that orientated in a North-up manner received
a value of 7.0. Therefore, it can be concluded that road names should be orientated according to the rotation angle of the road segments for scale level 1:2500. On the other hand, road names orientated according to the rotation angle of the road segments received a value of 6.5 for the perceived map complexity while that orientated in a North-up manner received a value of 3.9 for scale level 1:5000. Thus, it could be concluded that road names should be orientated in a north-up manner for the working scale level (1:5000).

The faded out effect to be applied to the road names received a perceived map complexity value of 4.5 for scale level 1:2500 and a value of 3.9 for scale level 1:5000, while the representation without the faded out effect received values of 7.0 and 6.6 for the two scale levels respectively (Table 6.3). Therefore, it could be concluded that the faded out effect to be applied to the road names which were not in close proximity of the vehicle has proved its effectiveness in map perception.

For the symbol design, results from Table 6.4 showed that the direction restriction symbols replicating the road signs produced by Transport Department received a value of 4.3 while its simplified version received a value of 5.7 for scale level 1:2500. For scale level 1:5000, the direction restriction symbols replicating the road signs produced by Transport Department received a value of 3.8 while its simplified version received a value of 5.1. Accordingly, it could be concluded that the direction restriction symbols replicating the road signs produced by Transport Department were less complex than its simplified counterparts for both of the scale levels 1:2500 and 1:5000.

For the presentation of landmarks, the one by names of landmark received a value of 6.3 while the one by perspective icons received a value of 4.4 for scale level 1:2500. For scale level 1:5000, the presentation by names of landmarks received a value of 6.6 while that by perspective icons received a value of 3.9. Thus, it could be conclude that the presentation of landmark by perspective symbols have gained less perceived map complexity compared with the presentation by names for both of the scale levels.
For the design of the planned route, results showed that it should better be presented by three different colors according to the vehicle's position, which are (i) part of route that the vehicle has already navigated; (ii) part of route that the vehicle is navigating in; and (iii) part of route that the vehicle is going to navigate (Table 6.5). It received the lowest perceived map complexity with a value of 4.3 for scale level 1:2500 and with a value of 4.0 for scale level 1:5000 while the values for others ranged from 4.8 to 6.3.

The use of buffer zones to create dynamic effect, the multi-scale presentation and the function for calculating the restricted road area proved their effectiveness in map perception. The map also gained positive comments in the map evaluation process suggested by Dent (1993). Since the map complexity can always be changed by stimulating different content layers, the dynamic map designed in this study can be applicable to many means of output, e.g. built-in vehicle navigation system, notebook computer and ArcPad.

In general, it was found that the preferred form of multi-scale dynamic map for land vehicle navigation had the following cartographic characteristics:

a. Different content-levels with different representation should be contained in different scale levels which could be changed by zooming in and out.

b. Prominence of map contents should be changed in a dynamic way according to the vehicle's position, where different visual variables and dynamic variables should be used for different map contents.

c. Road segments in the central display area defined by the vehicle position should be highlighted for a better perception.

d. Direction restriction should replicate the road signs produced by the local transport department.

e. Landmark symbols should be presented by perspective icons.

f. Planned route should better be presented by three different colors according to the vehicle's position, which are (i) part of route that the vehicle has already navigated; (ii) part of route that the vehicle is navigating in; and (iii) part of route that the vehicle is going to navigate.
7.3 Limitations and Recommendation for Future Research

The first consideration was about the fidelity of the proposed dynamic map under actual navigation conditions. As mentioned before, all the experiments were carried out in a static environment. There was no information about how the users perceive the map and how they relate the map to the actual environment. Findings that listed in session 7.2 may not still be factual under real dynamic environment when the drivers have to perceive data from different sources in a divided attention situation. However, the findings in this study provide guidelines which can be used as a platform for further research. To simplify the experimental procedures and let alone the integration of GPS positioning system with the vehicle, one may wish to consider the use of a driving simulator employed by Watanabe et al (1998). It consisted of a vehicle mockup fitted with a small monitor, a large forward screen, a video projector, a graphic engineering workstation and other devices. A simulated situation was produced where a test subject was traveling along a predefined route and output the maps to the monitor.

The second consideration was about the projection of the map data. In this study, multi-scale levels of map content were presented and achieved by zooming in and out. However, it would have shortcomings that the scales shown were discrete and operation with the interface is involved in order to change the scale. Those shortcomings could be overcome by employing a bird’s-eye view map which was introduced by one developer of route guidance systems in Japan. The field of vision for the driver was placed above the ground so that the route is viewed in perspective. It can provide both detailed and wide-area information simultaneously in a single display. Detailed information gives details of the area around the vehicle’s current location in a local sense (e.g. the configuration of an approaching intersection), while wide-area information shows the fairly distant area in a global sense. The former one will be shown in larger scale while the latter one will be shown in smaller scale. Contrasting with the discrete scale of traditional map display, scale of the bird’s-eye view map is varied continuously. It also provides a wide range of scale from large one showing the nearby area in detail to small one showing the view of a fairly distant area. Therefore, cumbersome operation of changing map scale can be eliminated.
Providing the two types of information at the same time can guide the driver to the destination accurately with a reassured feeling. The driver is also provided with a natural view as if he/she were a bird or in a plane looking down at the ground. The effectiveness of the bird's-eye view map was evaluated and confirmed in a test carried out by Watanabe et al. in 1998 (Watanabe et al., 1998), where the bird's-eye view map was compared with plan view and 3D view maps for the convenience and effectiveness through the eyes of a number of test subjects.

However, the working platform employed in this study doesn't have any built-in function to support perspective view of map. If the bird's-eye view map had to be generated, every single coordinate of all the map contents had to be transformed using the method of perspective projection. A huge amount of computation load would be involved which was fairly not feasible for a smooth program run. Therefore, a plan view map was employed in this study instead of the bird's-eye view one.

The third consideration was related to the overall map design. Sena (1997) suggested that maps to be used in day and night time should have different color palette. Palettes with minimum luminance sufficient for the driver to distinguish features and the vehicle's position should be used at night, while the external environment provides both illumination of the display and glare on the display's surface. It was also suggested that the vehicle navigation system should provide brightness control to change the display's luminance in order to meet the changing daytime illumination levels. Those factors should be considered in the map design process in order to make the map more practical.

Dynamic maps to be applied in land vehicle navigation have the potential to provide dynamically changing traffic and navigation information to plan or re-plan routes. This can be broadcasted by traffic management centers using radio signal or through computer networks. Information such as road status (traffic volume), parking availability and places of traffic accidents can be obtained. Consequently, information obtained by users would be more flexible, specialized and reliable. The use of visual variables applying to those new information on the navigation map have to be explored.
The objective of the above recommendations was to suggest modifications for the dynamic map in order to make it more effective in land vehicle navigation. Since there were limitations when designing the map, it is necessary to be improved and modified in various aspects for practical use. There is much room for improvement in presenting the information on the navigation maps. More research in this area is needed to determine the best method of aiding the driver with useful and effective information without reducing driver safety.
REFERENCES


Engen, 1972.


References


References


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References


APPENDIX
PROGRAMMING LISTING

Include "MapBasic.def"
Include "BigCircle.def"

Dim bldgup, bldgdown as integer
Dim rdup, rddown as integer

Sub Main()
Open File "c:\set.cfg" For Input As #3

Input #3, MapLocat
Input #3, WorkSpaceLocat
Input #3, RouteLocat
Input #3, CoordLocat
Call LoadWorkSpace
Call Animation_Init
Chk_Status = 0
Create Menu "Demo" As
"Restriction.." Calling Restriction,
"Start Normal.." Calling StartSub,
"Start Routing.." Calling StartRoute,
"Reset.." Calling Reset,
"End.." Calling EndSub
Alter Menu "Tools" Add "|-",
"Demo" as "Demo"

End Sub

Sub Reset()

Dim i as integer
Call SetSub(i)

End Sub

Sub Restriction()

Dim s_time as string
Dim temp_hour as string
Dim hour as float
s_time = Time(24)

hour = val(s_time)
Note "Current time is " + s_time + ". Corresponding restricted road will be shown in orange."

if hour < 7 then
    Open Table "C:\My Documents\mapbasic\pro2\Map\restrict24" As restrict24
    Add Map Auto Layer restrict24
end if

if hour >= 7 And hour < 10 then
    Open Table "C:\My Documents\mapbasic\pro2\Map\restrict0-7" As restrict7
    Add Map Auto Layer restrict7
end if

if hour >= 10 And hour < 16 then
    Open Table "C:\My Documents\mapbasic\pro2\Map\restrict10-16" As restrict10
    Add Map Auto Layer restrict10
end if

if hour >=16 And hour < 19 then
    Open Table "C:\My Documents\mapbasic\pro2\Map\restrict16-19" As restrict16
    Add Map Auto Layer restrict16
end if

if hour >=19 And hour < 24 then
    Open Table "C:\My Documents\mapbasic\pro2\Map\restrict19-24" As restrict19
    Add Map Auto Layer restrict19
end if

End Sub

Sub StartRoute()
    Chk_Status = 1
    Open Table RouteLocat As Route Interactive
    Add Map Auto Layer Route
    Call StartSub
End Sub

Sub StartSub()
    Dim i AS integer
    Dim j as integer
    Dim x as logical
Dim MapWin_ID as integer
Dim TabStatus as Logical
Dim MapZoom as integer

Open File CoordLocat For Input As #1

ProcessTimes = 0
Call Animation_Init
Call InitDisplayObject

' == the Table status for selecting the feature

MapWin_ID = FrontWindow()
MapZoom = MapperInfo(MapWin_ID, MAPPER_INFO_SCALE)

If MapZoom < 5 then
    ScaleType = 1
else
    If MapZoom = 5 then
        ScaleType = 2
    else
        If MapZoom = 10 then
            ScaleType = 3
        else
            If MapZoom >= 20 then
                ScaleType = 4
            End if
        End if
    End if
Else
    ScaleType = ScaleType + 1
End if

x = FALSE
do
    For i = 1 to 30000
        Next
        input #1, DDEx, DDEy
        Curr_X = DDEx
        Curr_Y = DDEy
        Call GpsPoint
        Old_X = DDEx
        Old_Y = DDEy
    Loop while Not EOF(1) and x = FALSE

Close File #1
End Sub

' set upper left and lower right value for
' GPS move point

Sub WinChangedHandler()

OnError GoTo errproc

If WindowInfo(gMapMainWinID, Win_Info_Type) = WIN_MAPPER
    Then
        gWinUL.x = (MapperInfo(gMapMainWinID,
                                Mapper_INFO_MINX))+100
        gWinUL.y = (MapperInfo(gMapMainWinID,
                                Mapper_INFO_MINY))+100
        gWinLR.x = (MapperInfo(gMapMainWinID,
                                Mapper_INFO_MAXX))-100
        gWinLR.y = (MapperInfo(gMapMainWinID,
                                Mapper_INFO_MAXY))-100
    End If

errproc:
    Exit Sub

End Sub

Sub Animation_init()

Dim AnimTblName As String
Dim BasicObjTblName AS String

Set Event Processing Off

' ========= Init the Display Object table =========

AnimTblName = "c:\anim.tab"
If FileExists(AnimTblName)=TRUE Then
    Open Table AnimTblName as Anim_Tbl
    Drop Table Anim_Tbl
End If

' ===== Create the Display Object table =====

Create Table Anim_Tbl
    ( DispObjID Integer)
File AnimTblName
Create Map For Anim_Tbl  'make the table mappable
Set Table Anim_Tbl FastEdit On Undo Off

gMapMainWinID = FrontWindow()

Add Map
Window gMapMainWinID
Layer Anim_Tbl
Animate

gAnimWinID = FrontWindow()  'same value as gMapMainWinID

Set CoordSys NonEarth Units "m" Bounds
(800000,800000) (900000,900000)
Set Distance Units "m"
Set Window gMapMainWinID Title "Testing"

Set Event Processing On
End Sub

Sub InitDisplayObject()

  gDispObj.mode = 0
  gDispObj.position.x = 0
  gDispObj.position.y = 0
  gDispObj.posInAnimTbl = 0
  gDispObj.traceSymbol = MakeSymbol (34, BLACK, 6)

  Call InitAddDispObj2AnimTbl

End Sub

Sub InitAddDispObj2AnimTbl

  Dim i, k, j As Integer
  Dim x1, y1, x2, y2 as integer
  Dim tempSymbol As Symbol
  Dim tempObject As Object

  i = 0

  '======== Car Symbol ==========

  tempSymbol = MakeCustomSymbol
               ("targ1-32.bmp", RED, 18, 0)

  '======== init the Obj symbol in to anim_tbl ==========

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Create Point
    Into Variable tempObject
    (0,0)
    Symbol tempSymbol

    Insert Into Anim_Tbl( DispObjID, obj )
    Values( i, tempObject)
    gDispObj.posInAnimTbl = 0
'=== the location of the display object in the anim_table
'& it is assigned as 1..

End Sub

Sub GpsPoint()

    Dim currPoint as Point
    Dim oldPoint as Point
    Dim currDispObjID as Integer
    Dim I as integer
    Dim currUnit as string

'---extract the input data to internal var

    currPoint.x = DDEx    'input data value from file
    currPoint.y = DDEy
    currDispObjID = I

    oldPoint.x = gDispObj.position.x
    oldPoint.y = gDispObj.position.y

'put the input data for display
    gDispObj.position.x = currPoint.x
    gDispObj.position.y = currPoint.y

    If IsPtInDisplayWin(currPoint) <> TRUE then
        Set Map Window gMapMainWinID Center (currPoint.x, currPoint.y ) 'Smart Redraw
    End If

    Call Move_Point(currDispObjID, currPoint, oldPoint)

    Call Sel_feature(currPoint)

End Sub

Sub Sel_feature(currPoint as Point)

    Dim BufferCircle as object
    Dim Temp_Obj as object

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Dim Row_No, i, j, k as integer
Dim Reset_optn as integer
Dim Line_style As PEN
Dim NewFont, NewFont2, OldFont, OldFont2 as Font
Dim CurrSymbol as Symbol
Dim NewSymbol, NewSymbolStyle as symbol
Dim SymbolName as String
Dim SymbolSize as integer
Dim Symbol_X as float
Dim Symbol_Y as float
Dim Check as Logical
Dim PassLink as PEN
Dim CurrLink as PEN
Dim OldLine_Style as PEN
Dim FontColor as integer
Dim FontStyle as Font

'=== The setting of the ground change===
Dim BigCircle as Object
Dim OldGround as Brush
Dim NewGround as Brush

BufferCircle = CreateCircle
    (currPoint.X, currPoint.Y, 10)
BigCircle = CreateCircle(currPoint.X, currPoint.Y, 250)
Line_Style = MakePen (4,2,RED)

'=== routning part ===

if Chk_Status = 1 then
    PassLink = MakePen (3,2,BLUE*80)
    CurrLink = MakePen (3,2,GREEN*50)

if processTimes = 0 then
    Select * From route where route.obj partly within
    BufferCircle into Query1_tab
    Set TABLE route USEREDIT ON
    Row_No = TableInfo (Query1_tab, TAB_INFO_NROWS)

if Row_No > 0 Then
    Fetch rec 1 From Query1_tab
    OldLink_ID = Query1_tab.id
    Temp_Obj = Query1_tab.obj
    Alter Object Temp_Obj
    info OBJ_INFO_PEN, CurrLink
    Update Query1_tab set Obj = Temp_Obj
where rowid = 1
End if

ELSE

Select * From route where route.obj partly within
   BufferCircle into Query1_tab
NewLink_ID = route.id
if OldLink_ID <> NewLink_ID Then

   Select obj From route where
      route.id = OLDLink_ID into Temp_tab
   Temp_Obj = Temp_tab.obj
   Alter Object Temp_Obj
   Info OBJ_INFO_PEN, PassLink
   Update Temp_tab Set Obj = Temp_Obj where
      rowid = 1

   Fetch rec 1 From Query1_tab
   Temp_Obj = Query1_tab.obj
   Alter Object Temp_Obj
   Info OBJ_INFO_PEN, CurrLink
   Update Query1_tab set Obj = Temp_Obj where
      rowid = 1
   OldLink_ID = NewLink_ID

End if

End if

Else

if ScaleType = 2 then '===== ctrlint 5000
   OldLine_Style = Makepen (1,2,BLUE)
   Line_Style = MakePen (2,2,RED)
   Select * From ctrline where ctrline.obj partly
      within BufferCircle into Query1_tab
   NewLink_ID = ctrline.id
   if OldLink_ID <> NewLink_ID Then
      Set TABLE ctrline USEREDIT ON
      Select obj From ctrline where
         ctrline.id = OLDLink_ID into Temp_tab
      Temp_Obj = Temp_tab.obj
      Alter Object Temp_Obj
      Info OBJ_INFO_PEN, OldLine_Style
      Update Temp_tab Set Obj = Temp_Obj where
         rowid = 1
      Fetch rec 1 From Query1_tab
      Temp_Obj = Query1_tab.obj
      Alter Object Temp_Obj
      info OBJ_INFO_PEN, Line_Style
Update Query1_tab set Obj = Temp_Obj where
rowid = 1
OldLink_ID = NewLink_ID

End if

'===== Change color of polygon inside the "BigCircle" ====
OldGround = MakeBrush(2,RGB(255,255,176),-1)
For i = 1 to 50 '===== Reset the Rec not
 'in Buffer Zone ====
  if QueryG.BigId(i) <> 0 AND
  QueryG.BigId(i) < 1000 Then
  Select * From bkgd where bkgd.obj within
  BigCircle AND bkgd.id = queryG.BigId(i)
  into QueryG_tab
  Row_No = TableInfo (QueryG_tab, TAB_INFO_NROWS)
  if Row_No = 0 Then
  Select Obj From bkgd where
  bkgd.id = QueryG.BigId(i) into Temp_tab
  Temp_Obj = Temp_tab.obj
  Alter Object Temp_Obj
  Info OBJ_INFO_BRUSH, OldGround
  Update Temp_tab Set Obj = Temp_Obj where
  rowid = 1
  End if
  End if
Next
NewGround = MakeBrush(2,RGB(232,208,255),-1)
Select * From bkgd where bkgd.obj within BigCircle
into QueryG_tab
Row_No = TableInfo (QueryG_tab, TAB_INFO_NROWS)
For i = 1 to Row_No
  Fetch rec i From QueryG_tab
  if QueryG_tab.id < 1000 then
  Temp_Obj = QueryG_tab.obj
  Alter Object Temp_Obj info OBJ_INFO_BRUSH, NewGround
  Update QueryG_tab set Obj = Temp_Obj where
  rowid = i
  End if
  queryG.BigId(i) = queryG_tab.id
Next
End If

End if

if ScaleType = 2 then '===== 5000

NewFont = MakeFont ("Arial", 0, 24, RED,-1)
OldFont = MakeFont ("Arial", 0, 13, Blue,-1)
Set TABLE bldg_name USEREDIT ON

For i = 1 to 5  '== Reset the Rec not within
 'Buffer Zone ==
if Query3.id(i) <> 0 Then
  Select * From bldg_name where bldg_name.obj
  partly within BufferCircle AND
  bldg_name.id = query3.id(i) into Query3_tab
  Row_No = TableInfo (Query3_tab, TAB_INFO_NROWS)
  if Row_No = 0 Then
    Select obj From bldg_name where bldg_name.id =
    Query3.id(i) into Temp_tab
    Temp_Obj = Temp_tab.obj
    if bldgdown = 0 then
      Alter Object Temp_Obj Geography OBJ_GEO_MAXX,
        (ObjectGeography
         (Temp_Obj, OBJ_GEO_MAXX)-30)
      Alter Object Temp_Obj Geography OBJ_GEO_MAXY,
        (ObjectGeography
         (Temp_Obj, OBJ_GEO_MAXY)-30)
      Info OBJ_INFO_TEXTFONT, OldFont
      Update Temp_tab Set Obj = Temp_Obj where
        rowid = i
      bldgup = 0
      bldgdown = bldgdown + 1
    End if
  End if
End if
Next
Select * From bldg_name where bldg_name.obj partly
within BufferCircle into Query3_tab
Row_No = TableInfo (Query3_tab, TAB_INFO_NROWS)
For i = 1 to Row_no
  Set style font makefont("Arial", 0, 24, RED,BLUE)
  Fetch rec i From Query3_tab
  Temp_Obj = Query3_tab.obj
  if bldgup = 0 then
    Alter Object Temp_Obj Geography OBJ_GEO_MAXX,
      (ObjectGeography(Temp_Obj, OBJ_GEO_MAXX)+30)
    Alter Object Temp_Obj Geography OBJ_GEO_MAXY,
      (ObjectGeography(Temp_Obj, OBJ_GEO_MAXY)+30)
    Alter Object Temp_Obj info OBJ_INFO_TEXTFONT,
      NewFont
    bldgup = bldgup + 1
    Bldgdown = 0
  end if
  Update Query3_tab set Obj = Temp_Obj where
    rowid = i
  query3.id(i) = query3_tab.id
Next

'== checking the color of the Old Text object ==
do
i = 1
Fetch rec i From rdname
FontStyle = objectInfo
    (rdname.Obj,OBJ_INFO_TEXTFONT)
FontColor = StyleAttr(FontStyle,FONT_FORECOLOR)
i = i+1
Loop While FontColor = 255

NewFont = MakeFont ("Arial",1,24,BLUE,-1)
OldFont = MakeFont ("Arial",0,13,FontColor,-1)

'==== Reset (rdname) the Rec not within Buffer Zone ====
For i = 1 to 5
if Query5.id(i) <> 0 Then
    Select * From rdname where rdname.obj partly
        within BufferCircle AND rdname.id =
            query5.id(i) into Query5_tab
    Row_No = TableInfo (Query5_tab, TAB_INFO_NROWS)
if Row_No = 0 Then
    Select obj From rdname where rdname.id =
        Query5.id(i) into Temp_tab
    Temp_Obj = Temp_tab.obj
if rddown = 0 then
    Alter Object Temp_Obj Geography OBJ_GEO_MAXX,
        (ObjectGeography
            (Temp_Obj, OBJ_GEO_MAXX)-35)
    Alter Object Temp_Obj Geography OBJ_GEO_MAXY,
        (ObjectGeography
            (Temp_Obj, OBJ_GEO_MAXY)-35)
    Alter Object Temp_Obj Info OBJ_INFO_TEXTFONT,
        OldFont
    Update Temp_tab Set Obj = Temp_Obj where
        rowid = 1
    rdup = 0
    rddown = rddown + 1
End if
End if
End if
Next

Select * From rdname where rdname.obj partly within
    BufferCircle into Query5_tab
Row_No = TableInfo (Query5_tab, TAB_INFO_NROWS)
For i = 1 to Row_no
    Fetch rec i From Query5_tab
Temp_Obj = Query5_tab.obj

if rdup = 0 then
    if ObjectGeography
        (Temp_Obj, OBJ_GEO_TEXTANGLE) <> 0 then
            Alter Object Temp_Obj Geography OBJ_GEO_MAXX,
            (ObjectGeography(Temp_Obj, OBJ_GEO_MAXX)+35)
        Alter Object Temp_Obj Geography OBJ_GEO_MAXY,
            (ObjectGeography(Temp_Obj, OBJ_GEO_MAXY)+35)
    Else
        Alter Object Temp_Obj Geography OBJ_GEO_MAXX,
            (ObjectGeography(Temp_Obj, OBJ_GEO_MAXX)+35)
        Alter Object Temp_Obj Geography OBJ_GEO_MAXY,
            (ObjectGeography(Temp_Obj, OBJ_GEO_MAXY)+35)
    End if
    Alter Object Temp_Obj info OBJ_INFO_TEXTFONT,
        NewFont
    rdup = rdup + 1
    rddown = 0
end if
Update Query5_tab set Obj = Temp_Obj where
    rowid = i
    query5.id(i) = query5_tab.id
Next

End IF

'==== For the multi selection in the buffer(Line) ====
if ScaleType = 1 or ScaleType = 2 then

    OldLine_Style = Makepen (1,2,BLACK)
    Set TABLE rdseed2 USEREDIT ON

'==== Reset the Rec not within Buffer Zone =====
For i = 1 to 5
    if Query2.id(i) <> 0 Then
        Select * From rdseed2 where rdseed2.obj partly
            within BufferCircle AND rdseed2.id = query2.id(i)
        into Query2_tab
        Row_No = TableInfo (Query2_tab, TAB_INFO_NROWS)
        if Row_No = 0 Then
            Select obj From rdseed2 where rdseed2.id =
                Query2.id(i) into Temp_tab
            Temp_Obj = Temp_tab.obj
            Alter Object Temp_Obj
                Info OBJ_INFO_PEN, OldLine_Style
            Update Temp_tab Set Obj = Temp_Obj where rowid = 1
        End if
    End if
Next
'==== Update the Current rec in buffer zone & ==== 
'==== update the Old Rec array ====

Select * From rdseed2 where rdseed2.obj partly within
   BufferCircle into Query2_tab
Row_No = TableInfo (Query2_tab, TAB_INFO_NROWS)
For i = 1 to Row_No
   Fetch rec i From Query2_tab
   Temp_Obj = Query2_tab.obj
   Alter Object Temp_Obj
   info OBJ_INFO_PEN, Line_Style
   Update Query2_tab set Obj = Temp_Obj where rowid = i
   query2.id(i) = query2_tab.id
Next
End if

If ScaleType = 1 Then '==== 2500

Set TABLE s2500 USEREDIT ON
i = 1
   '==== Reset the Rec not in Buffer Zone
if query3.id(i) <> 0 Then
   Select * From s2500 where s2500.obj partly within
      BufferCircle AND s2500.id = query3.id(i) into
      Query3_tab
Row_No = TableInfo (Query3_tab, TAB_INFO_NROWS)
if Row_No = 0 Then
   Select obj From s2500 where s2500.id = Query3.id(i)
      into Temp_tab
   Temp_Obj = Temp_tab.obj
   OldFont = MAKEFONT("Arial", 0, 10, 12632256, -1)
   Alter Object Temp_Obj
   Info OBJ_INFO_TEXTFONT, OldFont
   Update Temp_tab Set Obj = Temp_Obj where rowid = 1
   End if
End if

Select * From s2500 where s2500.obj partly within
   BufferCircle into Query3_tab
Row_No = TableInfo (Query3_tab, TAB_INFO_NROWS)
if Row_No <> 0 then
   Fetch rec i From Query3_tab
   Temp_Obj = Query3_tab.obj
   NewFont = MAKEFONT( "Arial", 1, 50, BLUE, -1)
   Alter Object Temp_Obj
   info OBJ_INFO_TEXTFONT, NewFont
   Update Query3_tab set Obj = Temp_Obj where rowid = i
   query3.id(i) = query3_tab.id
End if
End if
If ScaleType = 4 Then '---20k

Select * From content20k where content20k.obj partly within BufferCircle into Query3_tab
Row_No = TableInfo (Query3_tab, TAB_INFO_NROWS)
Set TABLE content20k USEREDIT ON
For i = 1 to Row_no
   Fetch rec i From Query3_tab
   Temp_Obj = Query3_tab.obj
   NewFont = MakeFont ("Arial",1,18,RED,White)
   Alter Object Temp_Obj
   info OBJ_INFO_TEXTFONT, NewFont
   Update Query3_tab set Obj = Temp_Obj where rowid = i
Next
End If

if ScaleType = 3 And ScaleType = 4 Then '====== 10k, 20k

Select * From rd20k where rd20k.obj partly within BufferCircle into Query2_tab
Row_No = TableInfo (Query2_tab, TAB_INFO_NROWS)
Set TABLE rd20k USEREDIT ON
For i = 1 to Row_no
   Fetch rec i From Query2_tab
   Temp_Obj = Query2_tab.obj
   Alter Object Temp_Obj
   info OBJ_INFO_PEN, Line_Style
   Update Query2_tab set Obj = Temp_Obj where rowid = i
Next
End If

if ScaleType = 3 then '===== 10000

Select * From S10000 where S10000.obj partly within BufferCircle into Query3_tab
Row_No = TableInfo (Query3_tab, TAB_INFO_NROWS)
Set TABLE S10000 USEREDIT ON
For i = 1 to Row_no
   Fetch rec i From Query3_tab
   Temp_Obj = Query3_tab.obj
   NewFont = MakeFont ("Arial",1,18,RED,White)
   Alter Object Temp_Obj
   info OBJ_INFO_TEXTFONT, NewFont
   Update Query3_tab set Obj = Temp_Obj where rowid = i
Next
End If

if ScaleType <> 4 then '==== In 2500, 5K, 10K =======
Select * From direction where direction.obj partly within BufferCircle into Query4_tab
Row_No = TableInfo (Query4_tab, TAB_INFO_NROWS)
Set TABLE direction USEREDIT ON
For i = 1 to Row_No
  Fetch rec 1 From Query4_tab
  Temp_Obj = Query4_tab.obj
  CurrSymbol = ObjectInfo(Temp_obj,OBJ_INFO_SYMBOL)
  SymbolName = StyleAttr(CurrSymbol,SYM_CUSTOM_NAME)
  SymbolSize = StyleAttr(CurrSymbol,SYM_POINTSIZE)
  NewSymbol = MakeCustomSymbol (SymbolName,Green,36,0)
  Call FlashSymbol (i, NewSymbol, Temp_Obj)
  NewSymbol = MakeCustomSymbol (SymbolName,Green,12,0)
  Alter Object Temp_Obj
    info OBJ_INFO_SYMBOL, NewSymbol
    Update Query4_tab set Obj = Temp_Obj where rowid = i
Next
End if

processTimes = 1

For j = 1 to 2500
Next

End Sub

Sub FlashSymbol (row_no as integer, CurrSymbol as Symbol, FlashObj as Object)
  Dim i,j as integer
  Dim CoverSymbol as Symbol
  CoverSymbol = MakeCustomSymbol
    ("Cover.bmp", green, 36,0)
  for i = 1 to 11
    Do Case i
      Case 1,3,5,7,9,11
        Alter Object FlashObj
          info OBJ_INFO_SYMBOL, CoverSymbol
      Case 2,4,6,8,10
        Alter Object FlashObj
          info OBJ_INFO_SYMBOL, CurrSymbol
    End Case
  Update Query4_tab set Obj = FlashObj where
rowid = row_no

For j = 1 to 4000
    Next

Next

End Sub

Sub SetSub(option as integer)
    Dim Temp_Obj as object
    Dim Row_No, i as integer
    Dim Style1, style2 as Pen
    Dim NewFont as Font
    Dim CurrSymbol, NewSymbol as Symbol
    Dim SymbolName as String
    Dim SymbolSize as integer
    Dim TabName2, TabName3, tabName4 as String

    Style1 = MakePen (1,2,Blue)
    Style2 = MakePen (1,2,Black)
    Set style font makefont("Arial", 0, 24, RED,BLUE)
    NewFont = MakeFont ("Arial",1,24,BLUE,White)

    '=== Reset the feature attribute===
    Do Case ScaleType

    Case 1
        TabName2 = "rdseed2"
        TabName3 = "S2500"
        TabName4 = "direction"

    Case 2
        TabName2 = "rdseed2"
        TabName3 = "bldg_Name"
        TabName4 = "direction"

    Case 3
        TabName2 = "rd20k"
        TabName3 = "S10000"
        TabName4 = "direction"

    Case 4

End Sub
TabName2 = "rd20k"
TabName3 = "content20k"

End Case

if option = 0 then

Set TABLE ctrline USEREDIT ON
Row_No = TableInfo (Query1_tab, TAB_INFO_NROWS)
For i = 1 to Row_no
    Fetch rec i From Query1_tab
    Temp_Obj = Query1_tab.obj
    Alter Object Temp_Obj
    info OBJ_INFO_PEN, Style1
    Update Query1_tab set Obj = Temp_Obj where rowid = i
Next

end if

if option = 0 or option = 1 then

Set TABLE TabName2 USEREDIT ON
Row_No = TableInfo (Query2_tab, TAB_INFO_NROWS)
For i = 1 to Row_no
    Fetch rec i From Query2_tab
    Temp_Obj = Query2_tab.obj
    Alter Object Temp_Obj
    info OBJ_INFO_PEN, Style2
    Update Query2_tab set Obj = Temp_Obj where rowid = i
Next

Set TABLE TabName3 USEREDIT ON
Row_No = TableInfo (Query3_tab, TAB_INFO_NROWS)
For i = 1 to Row_no
    Fetch rec i From Query3_tab
    Temp_Obj = Query3_tab.obj
    Alter Object Temp_Obj
    info OBJ_INFO_TEXTFONT, NewFont
    Update Query3_tab set Obj = Temp_Obj where rowid = i
Next

if ScaleType <> 4 Then

Row_No = TableInfo (Query4_tab, TAB_INFO_NROWS)
Set TABLE TabName4 USEREDIT ON
For i = 1 to Row_no
    Temp_Obj = Query4_tab.obj

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CurrSymbol = ObjectInfo
  (Temp_obj, OBJ_INFO_SYMBOL)
SymbolName = StyleAttr
  (CurrSymbol, SYMBOL_CUSTOM_NAME)
SymbolSize = StyleAttr
  (CurrSymbol, SYMBOL_POINTSIZE)
NewSymbol = MakeCustomSymbol
  (SymbolName, Green, 18, 0)
Alter Object Temp_Obj
  info OBJ_INFO_SYMBOL, NewSymbol
Update Query4_tab set Obj = Temp_Obj where
  rowid = i
Next

End if

If ScaleType = 5 Then
  Set TABLE rname USEREDIT ON
Row_No = TableInfo (Query5_tab, TAB_INFO_NROWS)
For i = 1 to Row_no
  Fetch rec i From Query3_tab
  Temp_Obj = Query3_tab.obj
  Alter Object Temp_Obj
  info OBJ_INFO_TEXTFONT, NewFont
  Update Query3_tab set Obj = Temp_Obj where
  rowid = i
Next
End If

End If
End Sub

Sub Move_Point(currDispObjID as Integer, currPoint as Point, oldPoint as Point)
  Dim tempDispObj as Object

'====== Create the move Object

FETCH REC gDispobj.posInAnimTbl FROM Anim_Tbl
tempDispObj = Anim_tbl.obj

'====== update the location of display object

Alter Object tempDispObj Geography OBJ_GEO_POINTX, currPoint.x
Alter Object tempDispObj Geography OBJ_GEO_POINTY, currPoint.y
Update Anim_Tbl Set Obj=tempDispObj where Rowid =
gDispObj.PosInAnimTbl

End Sub

Function IsPtInDisplayWin(inPoint as Point) as Integer
    IsPtInDisplayWin = FALSE
    If (inPoint.x > gWinUL.x And inPoint.x < gWinLR.x
       And inPoint.y > gWinUL.y And inPoint.y < gWinLR.y)
       Then
           IsPtInDisplayWin = TRUE
       end if
    End Function

Sub EndSub()
    Dim AnimTblName As String
    AnimTblName = "c:\anim.tab"
    If FileExists(AnimTblName)=TRUE Then
        Open Table AnimTblName as Anim_Tbl
        Drop Table Anim_Tbl
    End If
    if Chk_Status = 1 Then
        Close Table Route
    End if
    Chk_Status = 0
    processtimes = 0
End Sub