World Applied Sciences Journal 3 (Supple 1): 101-106, 2008
ISSN 1818-4952
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Automatic Map Scaling in Car Navigation Systems Using Context-aware Computing

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Abstract: Today, car navigation system is one of the most important applications of navigation system that is frequently used by drivers. Quality of maps, presented to drivers, has a direct impact on usability and performance of the system. In this context, displaying maps in various scales which are adapted to user's conditions and situations is a vital issue. In other words, users in different situations need maps with various scales to fulfill their information requirements. Since, using car navigation system is a secondary task for drivers (elementary task is driving and controlling cars) therefore, selecting and presenting maps with proper scale must be accomplished intelligently and automatically by the system. This paper proposes that in order to achieve the mentioned aim, context-aware computing should be utilized. Context-aware computing is a computing paradigm that enables systems to acquire current user's contexts and adapt their behavior accordingly. In this paper, the context-awareness potential for presenting maps with various scales which adapted to users contexts is evaluated. Also various contexts that may have an impact on map scale are studied and then an approach to select proper scale in these contexts is proposed. As a proof of the idea, a prototype context-aware car navigation system is developed, implemented and tested in parts of Tehran, capital city of Iran.

Key words: Car navigation . Context-aware computing . Map scale

INTRODUCTION

The ever increasing number of vehicles and growing complexity of the transportation networks make navigation systems more valuable and useful systems. Among them, car navigation system helps a driver to find the optimal route and to guide through the route safely. A well designed car navigation system enables drivers to get the best decisions with providing accurate and update navigation information. Hence drivers can avoid traffic congestion areas and save their times, as well as fuels.

A key concept for maps, those used in car navigation, is to display enough information in a suitable form. There are two basic forms for presenting navigational information to drivers; maps and voice commands. Maps enable users to have an entire picture of the planned route and also generate true perceptions in complex intersections. But voice commands are unable to perform these functions and only have a good performance for presenting turn-by-turn instructions. Therefore, maps are considered as essential part of all car navigation systems.In car navigation system, contents which are displayed on the maps, as well as representation of these contents (visualization of maps) must be in the forms that enable drivers to get their required information in a few glances.

MOTIVATION

Interacting with car navigation system is not the first task for drivers, because concentrating to the system may cause accidents. Many researches study the safe times that drivers allow to concentrate on displays of car navigation systems. According to [1], this time must be less than two seconds during driving. Then displaying maps in clear and readable form is very important issue in car navigation system. Maps used in current car navigation systems are often modeled after paper maps and have similar visual complexity [2]. Thus, displaying such complex maps on displays with limited sizes cause to messy and unreadable maps. Hence, often the special methods for abstracting the level of map's details are needed in order to increase readability of visual navigational information.

The context in which a user is performing his tasks has a strong connection to his information needs and controls the content as well as the visualization mode of the information [3]. Driver's context are changing time to time, accordingly, displaying the map should be

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changed. For example, a user needs more information when his/her car stopped, whereas while he/she drives fast, a map with low level of details is needed. Considering the above discussion, it is reasonable to say that in car navigation, it is essential to present maps with different (various) level of details or different scales. According to [4], car navigation requires data at a wide range of scales and at different levels of abstraction.

In this research, we evaluate that what scales are proper for different contexts in car navigation systems. We also suggest an approach that enables system to automatically decide which scales must be present at what context. To achieve this goal we propose to use context-aware computing.

The remainder of this paper is structured as follows. Section 2 describes the basic concepts of context-aware computing and the role of this type of computing in generating maps for car navigation with focusing on map scales. Section 3 discusses the context information that may be effective in car navigation system. Section 4 describes the proposed approach for determining proper scales and then explains our implementation of a prototype system. Finally, Section 5 offers concluding remarks.

CONTEXT-AWARE COMPUTING

Context-aware computing is one of the basic aspects of pervasive computing. This type of computing was introduced in 1992 by Olivetti Research Ltd (ORL) [5]. A context-aware computing system is a system composed of various hardware and software that are aware of context and can automatically adapt and respond to such context. Context awareness enables the system to take action automatically, reducing the burden of excessive user involvement and providing proactive intelligent assistance [6]. According to Dey and Abowed [7], context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves. There has been much work in identifying what such information can be, the structure of the information, how to represent such information and how to exploit context in specific applications. Contexts can include information such as location (e.g., of people or objects), time, execution state of applications, computational resources, network bandwidth, activity, user intentions, user emotions and conditions of the environment [8].

With this in mind, it is possible for car navigation systems to get current context information such as car position, speed of car, time of travel and so on and then adapt themselves with such contexts in order to present more relevant information to drivers.

We believe that, there are at least two major issues in car navigation which enforces context-awareness for selecting appropriate scales and presenting map with the selected scale: first, with the cars movement, the current context as well as required information will be changed continuously. Second, based on minimizing explicit interaction between driver and system, the system should sense context and change the scale accordingly.

CONTEXTS IN CAR NAVIGATION SYSTEM

According to the mentioned definition of context, one needs to find out how to select the relevant factors and ensure that they are taken into account in the application design phase, i.e., consider which context information will be relevant in the usage situation and have impact on the device or the user [9]. Until now, very few researches focus on the related context in navigation systems. ample *et al*.[10] categorized navigation-related contexts in four classes, namely:

- Skills and experience:
  - Experienced with maps, knowledge about signatures
  - Abstraction ability (turning the map to north)
  - Knowledge about environment
  - Familiar to features of map
  - Age, health
- Mode of movement:
  - By car
  - By bicycle
  - As pedestrian
- Reason for moving:
  - Direct path to goal (shortest, fastest path)
  - Tourist tour (specific distance, most scenery, secure or easy route (e.g. hiking))
- External factors:
  - Rush hour, traffic jam, accidents, holidays
  - Road restrictions
  - Daytime/nighttime (objects cannot be seen in the dark, special objects are illuminated at night)
  - Summer/winter (restricted visibility because of trees and bushes in the summer time)

As one can see, the above categorization is for navigation in any modes i.e. car, bicycle and pedestrian. It is very simple to understand that designing a system varies based on different characteristics of modes. Also several contexts were disregarded such as position and speed of cars. So we offer a new categorization of context that specialized for car navigation system:

- Context about mobile
  - User's context such as: knowledge about environment, age, gender etc.
  - Car positions including both of absolute and relative position
  - Car's contexts such as type of car (motorcar, truck) etc.
- Context about movement
  - Speed
  - Velocity
  - Direction of move
  - Time
- Context about movement environment
  - Illumination level
  - Noise level
  - Type of the road
  - Weather
- Context about motivation
  - Reason for moving
  - Destination.

The above mentioned contexts can have impacts on map contents and map visualization; however, they may not be effective for determining a proper map scale. Also, nowadays there are no appropriate sensing techniques to obtain the amount of contexts. Therefore, we consider only some contexts that could be sensed practically.

IMPLEMENTATION OF CONTEXT-AWARE CAR NAVIGATION SYSTEM

Case study: Tehran city: Tehran, capital city of Iran as one of the biggest and crowded cities in the world taken as the study area in this research. Transportation networks of the city became more and more complex with adding new roads in recent years. This complexity hardens the task of car navigation system to display clear navigational information. Also, there are inaccurate data (both in geometry and attribute) from this metropolis. Hence, we select a section of Tehran that showed in Fig. 1. The scale of the base maps that were used in this research was 1:2000 and other scales derived from these maps using several generalization techniques. The feature layers of the base maps includes; Roads layer (highway, major and minor roads), Block of buildings, Parcels, Point Of Interest (POI) and Landmarks.

SCALE MODELING

As mentioned before, due to the importance of user's attention to driving task, any objects that may cause to distract driver's concentration in display should be avoided. Drivers need to pay more attention to recognize the required information from map, if displays present a map with very high level of details. Scales of maps depend on level of details as well as the level of map zooming on display. It is clear that increasing details of a map increases the scale as well and vice versa.

Fig. 1: Elected area of Tehran and planned route

Table 1: Appropriate map scales based on three ranges of car speed

Car speeds	Appropriate scales	Details
V<20km/h	1.430555556	All roads of city, building blocks, parcels, land use(buildings, green area), POIs, landmarks, related text
20km/h<V<50km/h	3.513888889	All roads of city, building blocks, POIs(with symbols), landmarks, related text
V>50 km/h	1:10000	Major roads, landmarks on decision points, related text

In this section we consider just two important contexts related to scale, including car speed and screen size of a mobile device. Then we offer a model that consider the two contexts and determines proper scale based on the following relation.

$$s = S(v, l) \qquad (1)$$

v: Current car speed
l: Screen size of mobile device

Car speed: Map scale has a negative relation with car speed. In a simple word, when a car speeds up the scale of map must gets down in order to give information of wider extent of environment to drivers (relation 2).

$$v_i<v_j \Rightarrow S(v_i)>S(v_j) \qquad (2)$$

Vi and Vj: car speeds in time i and j
S (vi) and S (vj): scales of map in time i and j

Also, drivers do not need detailed information of their environment, when they are driving fast. Therefore, in high speeds, only major route elements, together with important landmarks in decision points should be displayed on map. So, car speeds are divided into three ranges and based on practical experiments, appropriate scales in every speed ranges are determined, as seen in Table 1.

SCREEN SIZE

Screen size of display devices is another important context that can have high impact on map scale. Existing and also probably future display devices will be of a limited size. This issue naturally prevents presenting all the details of the environment [11-13]. On the other hand, most of current car navigation systems could be run on various types of mobile devices with different screen sizes range from 2.4 inches for some models of PDAs to 12.1 inches in some types of tablet PCs. So, when the system runs on very small displays, this causes serious problems to a legible presentation of geodata. The data have to be strongly generalized without influencing the transfer of meanings [3]. Displaying the same maps which tailored for very small screens on larger screens causes to waste some space of display. Therefore, in this case, more details of information can be displayed on map without making negative impact on readability of it.

IMPLEMENTATION OF CONTEXT-AWARE CAR NAVIGATION SYSTEM

In order to implement the above concepts, a preplanned route-output of route planning module of car navigation systems-between two points in Tehran was utilized. Also, a file which contains information about car positions and car speeds in any time was generated to simulate sensors information (context information). Context-aware car navigation application read this file and based on positional information which is stored in the mentioned file, the current position of car mapped on display. Also, using car speed information and screen size of used device, proper scale is determined and map with this scale is generated using feature layers (which are resided in spatial database) to be displayed to users (Fig. 2). The context-aware car navigation application was implemented using Microsoft.NET compact framework 2.0. The mentioned application was deployed as Windows Mobile 5.0 smartphone application on two mobile devices; A tablet PC (SAMSUNG Q1B) with 7 inches screen size and a PDA (DELL Axim X51v) with 3.7 inches screen size. On account of small screen size map with scale 1:2000 cannot be displayed on PDA. So in the case of PDA, just map with scales 1:5000 and 1:10000 presented to drivers. If car speed is less than 50 km/h, then map scale 1:5000 is selected and in other speeds, map scale of 1:10000 is selected and presented.

CONCLUSIONS AND RECOMMENDATIONS

In this paper a major part of an ongoing research work on designing context-aware maps for car navigation system has been presented. This study focuses on the determination of proper map scales for car navigation system based on current context and adapting map with this scale automatically. During this study, we consider current user context as the most important factor to specify driver's required information. Therefore, we tried to put context-aware

(a) (b)

(c)

Fig. 2: Generated maps using context-aware car navigation system; a) speed < 20 km/h and screen size=7 inches, b) speed > 50km/h and screen size= 7 inches, c) speed < 50km/h and screen size= 3.7 inches

computing into maps in order to acquire context and adapt map presentation with this context. In addition, we emphasized the necessity of presenting maps with different level of details and scales in car navigation in order to increases readability of maps. Also we consider car's position, speed of the car and screen size of used device as effective contexts in determining map scale. Subsequently we offer an approach to select appropriate scale in any of these contexts.

However, there are many issues that needs for further research and experiment. For example, map scale may be depend on numerous other contexts (besides the speed and position of cars and displaying device characteristics) such as user cognitive issues, time, direction of movement, user preferences and so on. Therefore to improve the developed model which determined map scale, we need to identify more contexts that are related to scale and new methods to model and formulize these contexts. On the other hand, context-awareness has a high potential for adapting other elements of visualization and map rendering with user context. For example context-awareness can be used to adapt symbolization, the heading direction of maps and so on. Finally, we need for suitable methods for evaluating usability and performance of these systems.

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