SELECTED METHODOLOGICAL ASPECTS OF CREATION OF CARTOGRAPHIC PRESENTATION FOR THE NEEDS OF MOBILE SYSTEMS

Dariusz Gotlib
Department of Cartography, Warsaw University of Technology,
d.gotlib@gik.pw.edu.pl

Keywords: cartographic methodology, geographic data visualization, cartography visualizattion, mobile GIS, mobile cartography, car navigation systems, GPS, LBS

1. Introduction

The main objective of the project, which was implemented at the Department of Cartography, the Warsaw University of Technology (Project No. 0129/B/T02/2008/35 of the Ministry of Science and Higher Education) was to define the methodology of development of cartographic presentation (visualization) using mobile devices, as well as to propose and design new cartographic tools and determination of impacts of new technologies and conceptual solutions on the theory of cartography. Experiences and achievements which have been gained in the past in the field of mobile cartography (in particular Reichenbacher 2004, Nagi 2004, Chikako and Morishige 2007, Dillemuth 2007, Gartner and Cartwright 2007 and others) were reviewed within the Project. An attempt to order and develop those experiences was also made.
This paper presents only a part of performed research works and, due to those limitations, it concerns only selected aspects of preparation of the 2D presentation and concentrate on GPS navigational systems for driver. Recommendations concerning the 3D and video presentation, mobile systems for sailors, pilots, surveyors, and methods of construction of cartographic tools will be presented in a separate papers.

2. Research methodology

Designing cartographic visualization for the needs of a mobile systems requires utilisation of deep cartographic knowledge, and, on the other hand, familiarisation with teleinformation technologies, basics of computer science, as well as experiences related to utilisation of such systems.

The process of development of cartographic presentation methodologies for mobile systems, has been divided by the author into the following stages:

1) Analysis of the database content, structure and algorithms and technologies applied in mobile devices,
2) Selection of diversified areas, which require diversified approach to cartographic visualization (such as urban areas, arable lands, areas of scarce and dense road infrastructure),

3) Analysis of data generalisation issues in the real time mode and analysis of visualization of dynamic data, delivered to a user (such as limitations in traffic),
4) Selection of the best, practically used solutions and perceptual graphical operations in mobile systems,
5) Development of the test environment, which allows for investigations of visualization in mobile systems for various parameters of the outer environment and for various technological conditions of applied devices,
6) Investigations of test perception of cartographic presentations in market research using the „focus" and „questionnaire" methods,
7) Implementation of efficiency test for developed cartographic presentations and optimisation of cartographic visualization,
8) Preparation and testing of software, which supports activities of the map designer.

3. General assumptions of the methodology of creation of cartographic presentation

The basic rules of cartography are obligatory in the case of designing data visualization in mobile systems, but it is necessary to apply the slightly different methodology of works, utilisation of unconventional graphical operations, other methods of optimisation and specific working tools.

These results, first of all, from several conditions related to utilisation of cartographic visualization in mobile systems:

- the necessity to visualise data in a wide series of scales (starting from visualization of particular road lanes to the view at the state or the continent levels);
- the necessity to transfer more information than the amount of information presented on conventional maps at similar scales;
- shifting and rotating the map image during its utilisation;
- difficult conditions of observations of prepared presentations (various illumination conditions, observation angles, limited time for observation of presentation by users etc.);
- synchronisation of the map view with graphical and voice navigation guidelines;
- ensuring the variations in the presented content, depending on the user location in the space (context of the content, multi-resolution source data base);
- the need to display dynamic information (the route of travel, difficulties and obstacles in traffic, weather, detours etc.);
- small size of the display, which presents a map and related technical limitations;
- highly limited possibilities to utilise a map legend (or lack of such possibilities);
- the need to adjust the map graphics to the graphical style of the navigation application and the user preferences.

It has been pointed in the conclusions concerning the performed tests, the term of cartographic visualization (presentation) should be considered in a wider sense than before. This process should not be associated only with creation of the graphical image of the real situation. Creation of data visualization for the needs of a mobile system, means also the definition of an important part of the navigation application functionality, definition of methods of visualization of symbols of the route of travel, the route intermediate points, navigation arrows, images of traffic lanes, view of the horizon (sky) in perspective and three-dimensional presentations. The process of visualization should also include determination of scale thresholds and events, which results in the map scale changes during utilisation of the system.

It should be considered that the data presentation in the navigation system is not one map, presented at the given scale, with one set of cartographic symbols, but a complete set of component (partial) visualization, which must be considered as coherent entirety.

The methodology of creation of cartographic presentations for mobile systems should consider utilisation of other methods and techniques than in the case of analog cartographic works. It is possible and useful to use modern modelling languages, such as UML, the XML language and tools, allowing for optimisation and testing presentations with respect to its utilisation for various mobile devices. It should be remembered that, in most cases, creation of appropriate cartographic presentation requires the knowledge on specific features of the database and free manipulation of data stored in that database. Modern visualization will be usually based on MRDB type databases. It is particularly important for visualization of geographic data at small scales.

In order to formalise the process of creation of cartographic presentation and to consider its wider aspects, description of data presentation according to the model presented in Figure 1. has been proposed.

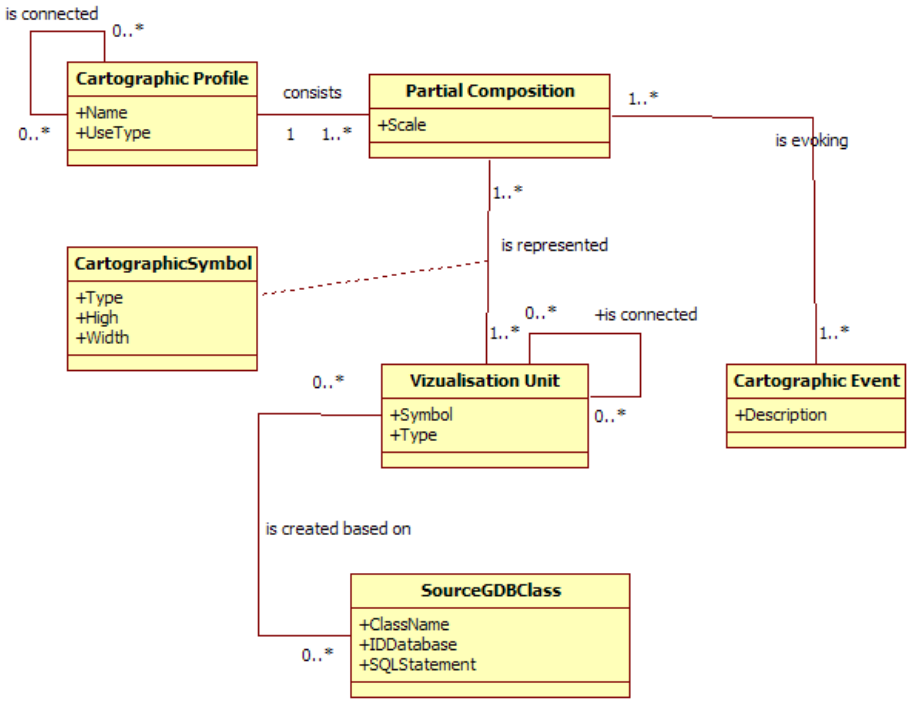

Figure 1. Cartographic Presentation Model. Diagram of classes which defines a way of describing the cartographic presentation.

The “Visualization unit” is the basis of the visualization project; it, first of all, is created as a result of operations performed on classes of the source geographical database. It may correspond to a specified object class, selected group of objects of a specified class (which meet the specified logical condition), a group of objects, which was created as a result of spatial analysis, a raster image, labels generated from attributes or a dynamic object, such as a generated route of travel. The visualization unit may be connected with another visualization unit, if, without it, it cannot be displayed on a map. The cartographic symbol is assigned to the visualization unit, distinguished in the first stage of the project, separately for each “Cartographic partial composition”. The term “cartographic partial composition” (or cartographic composition component) is understood as visualization at a specified scale, performed according to assumptions of a specified “Cartographic profile”. The cartographic profile is one of several data views, accessible from the user level, which is visually diversified and defined with respect to specified user demands, e.g. the daily profile, the night profile, the professional profile, the simplified profile, the standard profile and the touristic profile, the 2D and 3D profile (or combinations of those features). A set of scale thresholds is assigned to each profile; cartographic compositions components are defined for those thresholds. Relations may exist between those profiles, which allow for defining their sets, which create the complete cartographic visualistation. Particular “Partial compositions” are called due to specified “Cartographic events”, such as changes of the user’s speed, approaching the place of specified manoeuvres, using the scale change function by the user, approaching the city area by the use, approaching the traffic obstacles etc.

4. Selected stages of designing the cartographic presentation

Below, some elements and stages of creation of the cartographic presentation are discussed, which are characteristic for application of mobile systems.

4.1. Analysis of function of the navigation application

Development of the cartographic visualization starts from functional analysis of the navigation application, for which the presentation is prepared. It is particularly important to determine, which elements of the presentation may be designed using the cartographic tool, delivered by the application manufacturer, and which of them are the elements defined by the group of programmers. The further stages of the designing process are influenced by such functions and factor as: the possibility to switch between many cartographic profiles, the ways of operating the map scales, accessibility to the map legend, the possibility to use 2D and 3D views, the way of POI visualization (types of accessible symbols) and the way of displaying many objects located in the same spatial location (e.g. many POIs – MultiPOI) the way of generation of labels (static, dynamic), the possibility to locate labels on curves, accessibility of antialiasing, the

possibility to operate separately at small scales on generalised data files, applied algorithms of data generalisation. Unfortunately, in many cases, the cartographer must notice many limitations at this stage, which basically influence the entire process of designing the cartographic presentation.

4.2. Analysis of accessible database

The GIS type database is the source of spatial information in a mobile system. At the successive stage of designing the cartographic presentation its analysis should be performed together with required data processing (if this results from the performed analysis). The structure, content and accessibility of generalised data sets are evaluated. Using such data, elementary "visualization units" should be defined, identifiers should be assigned to those units and queries should be defined (e.g. SQL), which would allow for distinguishing them from the source database. It is particularly important to determine the accessibility of datasets, generalised to smaller scales, in the form of independent object classes or in the form of the Multiresolution/mulitirepresentation type database (MRDB).

Then data should be grouped into data directly used for navigation and auxiliary data. The key task is to group the road network into classes, creating coherent sub-graphs in such a way, that in the case of smaller scale, it would be possible to limit the number of displayed roads, what is required by optimisation procedures. The important element of the process is also to define relations between "visualization units" in a way that ensures the coherence of the cartographic visualizationn, i.e. to define, which elements should be displayed only in relations with other elements.
At the next step the hierarchy and priorities of displaying the „visualization units" are specified. They should be defined or available attributes, accessible in the source database („Display Class" „Drawing Order" or „Hierarchy Level") should be used.
Information is recorded in following the data model (Fig.1) in the structures of the applied database or in the xml format.

4.3. Definition of component (partial) compositions

Modern navigational and locating based systems offer potentially wide possibilities to modify cartographic visualization. Built-in clocks and calendars, as well as telecommunication tools, which acquire information concerning weather, may allow for presentation modification depending on the time of year and the weather. However, the majority of systems allow for manual selection of one of several cartographic profiles only.

Accessibility of many profiles, as well as the possibility of the user selection of those profiles is important for many reasons. One of them concerns the difficulties in development of one profile, which meets expectations of all users, since the users' taste and customs play an important role in this case. Having the function of reading various

versions of a map, it is possible to ensure the highest level of user satisfaction, not as a result of development of one, ideal presentation, but as a result of allowing the users to select the most appropriate versions, from their point of view. In general this way may be used as the only, reasonable way to perform the formulated objectives, particularly because the user often changes the map evaluation, comparing to the prior selection, as the map using process continues.

Since interactions between the user and the system may be increasing, it is possible to correct presentations even in dependence on the user's mood. Interesting experiments were, among others, performed in this field by (Chikako and Morishige 2007). However, this requires the continuation of further experiments and utilisation of the developed psychological knowledge.

Depending on destination of the system and the possibilities of the application, development of the complete cartographic visualistation of the mobile system means development of several or several dozens of profiles. Profiles are developed with consideration of the type of illumination in the time of using, the way of the system use, types of users, objectives of use, preferred colour palette, the quality and cartographic complexity, the display size.

Theoretically, in such a case it would be necessary to develop several dozens of profiles, resulting from combination of those parameters. However, in practice, the decision should be made, concerning the selection between 2 and 6 cartographic profiles and to independently control turning on and off some object classes within the functionality of the navigation application, what would allow for obtaining several dozens of versions of the map outlay. As the minimum, it is proposed to prepare the following cartographic profiles: the navigational daily standard profile, the navigational, "sunny" profile, the navigational night profile, the "localistation" profile;

The proposed methodology of designing cartographic visualistation assumes the necessity to present relations between particular profiles, being its components.

It is required to create the basic profile, which could allow for automatic or semi-automatic generation of derivative profiles, using the inheritance mechanism.

Distribution of simplified cartographic tools among the users may become very useful, which would allow them to semi-automatically create own profiles, consistent with individual preferences. It is necessary in this case to equip tools with creators and ready-to-use patterns of presentations.

4.4. Selection of scale thresholds and corresponding scope of the content

Although, in the case of spatial databases, the scale is generally not discussed, in the case of visualization it is necessary to consider this term. Although the user of the

navigation system has the impression of possible and flexible modifications of the scale, the cartographic presentation is mostly developed in a discrete (not continuous) way for selected scales only. Defining the optimum scales used for data presentation is an extremely important task of the cartographer. Another scale should be defined in the process of searching for localities, another one for searching for particular addresses and another scale should be specified when approaching to a complicated road junction or to the place of destination. The scale of the displayed map may be changed automatically or manually.

At the next stage of preparation of the cartographic presentation the scale thresholds, required by the system should be described or defined (if this is allowed by the software) and they should be initially assigned to ranges of content.

„The cartographic event" which mostly initiates the scale changing, is:

1) modification of the user velocity;
2) approaching the place of planned manoeuvres at a given distance;
3) entering a built-up area;
4) change of the mode of using the system: from navigation into location services;
5) calling for specified system function, e.g. „Show the entire route", „Find selected object", "Zoom-out the map", "Zoom-in the map".

Various systems use various methods of selection and modification of scale thresholds for the applied visualization of geographic data. Below an example of scale thresholds and initiating events are presented, which is used for NAVIGO application:

Initiating event	"Called" scale of partial cartographic presentation
Velocity higher than 90 km/h	scale 1:50 000
Velocity higher than 60 km/h and lower than 90 km/h	scale 1:20 000
Velocity lower than 60 km/h	scale 1: 10 000
Distance 600 m from the place of manoeuvres	scale 1: 10 000
Distance 300 m from the place of manoeuvres	scale 1: 5000
150 m from the place of manoeuvres	scale 1: 2000
Starting the function: „Show the entire route"	scale calculated basing on the MBR surrounding the object
Marking an object on a map after searching function	scale calculated basing on the MBR surrounding the object, and, in the case of point objects, scale 1:5 000 – 1:20 000 depending on category.
Starting the function „Zoom"	1:2000, 1:5000; 1:10 000;1:20 000; 1:50 000; 1:100 000; 1:200 000; 1:500 000;1 :1 000 000; 1:2

	000 000; 1:5 000 000; 1:10 000 000; 1:20 000 000.

Table 1. An example of scale thresholds and initiating events, applied in Navigo application (information from Navigo application developed by PPWK S.A)

A useful solution, which may be applied only when large displays are used, is to simultaneously present the terrain in two scales and two modes of operations. Besides the standard navigation mode the review mode is available with the permanent map orientation to the North.

Due to efficiency reasons the derivative, intermediate data sets are created, which allows for simplified review of a map at small and medium scales, in order to minimise the numbed of displayed objects. Such data may originate from the MRDB or they may be generated in the process of generalisation, in the course of preparation of the data set for the navigation system.

All operations pin the navigation system are performed on the database of the highest level of details and accuracy, but operations related to map reviewing are performed on generalised data. Utilisation of the MRDB databases may facilitate the process of visualization, since generalised objects at the derivative scales are closely related to source objects. Therefore it is easier to maintain the coherent cartographic presentation of the same object, represented by a linked, separate geometry at various scales.

In the case of data visualization in mobile systems it is not possible to utilise experiences and traditions resulting from the permissible scope of the content of conventional maps at the given scale (such as paper road maps). Those limitations result both, from the display resolution, from the influence of external factors (illumination) as well, as from the method of map utilisation itself (short, fast contact with a map during other operations connected to driving a car). It is not always necessary to develop such a rich content as in the case of conventional maps, since it is substituted by other system functions. This, in particular, concerns the navigation mode, when – in many cases - the user does not have to see the map content, listening to voice commands. A map is useful in the case of accessing complicated road junctions or when a rapid change of the route, caused by an unplanned obstacles, occurs. In the case of the „Location" or „Pedestrians' navigation" mode, differences between the content of conventional, analog and maps in the mobile system, are decreased.

4.5. Definition of names generation method on a map

At the next stage, information concerning the method of describing (labelling) on a map is assigned to "visualization units". Not all objects should and may be described. This largely depends on their number in the accessible database, the descriptive information quality and on destination of the system (for the standard navigation, or for the systems developed for tourists).

Due to information concerning the calculated route of travel, available in the graphical, descriptive and voice forms (for a vehicle, a pedestrian or for a ship), approach to placing labels on a map with respect to paper maps, is often modified. Technology allows for generation of labels which dynamically change their locations and their content, depending on parameters assumed by the system designer, what allows for, among other, displaying abbreviated labels together with decreasing the scale, or displaying full names at the largest scales, on lists of selections or results of searching. The availability of full and abbreviated names in the database may be particularly useful. Utilisation of abbreviated names may be important for small scales and in the case of using small displays.

In the case of car navigation it is not necessary to display all labels. Displayed labels may be limited, for example, to street names, which are crossed by the travel route. It is important to avoid labels at the angles which are considerably different than 0, 90, 180. First of all, streets which are crossed at angles close to 90^o should be described. In order to avoid situations when the planned travel routes are covered by the street labels, the street name may be separately displayed, for example, horizontally, at the bottom of a map.

A separate issue is the selection of fonts applied for descriptions on a navigation map. Fonts, which are well readable on conventional maps are not always well visible on a display of a mobile device. Usually, the fonts with serifs should be avoided. Basing on performed experiments Nagi (2004) recommended to apply Arial and Verdana fonts of the size of 8-10 points. The readability of the displayed image may be usually improved by placing the background under letters (mostly white background), the so-called, "halo" effect. This operation is also applied for conventional maps, but the "halo" effect may be of smaller size on conventional maps.

It should be also remembered that the font readability is strongly influenced by graphics of other map elements. In the case of street names this mainly concerns the street edges. In order to maintain the readability of labels, the street edges cannot be black, since serious graphic conflicts would occur in this case.

An important element, which influences the readability of labels on a mobile device, may be the utilisation of slightly bigger spaces between letters in particular words.

4.6. Assigning cartographic symbols to objects

After operations mentioned above selection and assigning of corresponding cartographic symbols to particular „visualization units" may be commenced.
Selection of colours on a map must consider specific features of displays of mobile systems, as well as conditions of using the system (day, night, intensive illumination by the Sun etc.). The amount of presently available devices, and technological differences between them, are considerably high. Therefore, attempts should be made aiming at

selection of such colours, which would result in the cartographic presentation looking well and similarly on various displays. As the recent tests show, any devices will not fully substitute empirical experiments. In the case of presentation, which is to be used in the conditions of limited natural illumination, selection of colours should be similar to conventional cartographic works. In the case of presentation, which is to be used under intensive Sun illumination it is necessary to increase the hue parameters, to eliminate gray graphical elements and to substitute the white „background" with the colour one. In the case of the night presentation it is useful to apply the dark background and to assign dark colours to objects, with the exception of elements which represent the road network, which should be clearly distinguished from other graphical elements. In the process of development the "night visualization" of geographic data, the cartographer should aim at maintaining the commonly accepted cartographic conventions (green – forests, blue – water etc.). Some map producers develop the „night" presentation of colours as automaticly inversion, what results in effects, which are incorrect from the cartographic points of view.

Application of area and linear patterns in the case of visualization of navigation data should be limited. Readability of such patterns is lower than in the case of conventional maps. Another issue is related to selection of appropriate widths of linear road symbols. As it turns out from performed tests, in the mode of location and planning the travel, exaggerations which are slightly bigger than in the case of conventional maps at the same scales, are sufficient. However, exaggeration should be much larger in the case of the mode of navigation. The best situation is when the street name is fully included in the road symbol. In the case of profile for the intensive Sun illumination, edges of symbols should be thickened. Detailed designing guidelines in this field, together with examples of visualization will be presented in the final publication of the project results, and they are partially described in (Gotlib 2008).

Assigning graphics to objects may be performed in a way, which is typical for GIS applications, but it seems reasonably and possibly to develop special creators. The task of such creators would be to select among many presentation patterns, to allow automation of the derivative profiles development process, such as the „Night" or the "Sun" profiles etc.

4.7. Optimisation of the cartographic visualistation in the context of efficiency of the navigation system

In the process of creation of cartographic visualization for mobile systems, the aspect related to optimisation is also very important. Although the power of mobile devices constantly grows, the volume and complexity of data, which should be made available to users also constantly grows and the methodology of cartographic presentation (3D views, pseudo-realistic views, displaying satellite and aerial images, operate with high speed and without any breaks. One of the key elements, which influences the operation speed, is cartographic data presentation, which requires that large numbers of objects

are read-in the device memory. Therefore, optimisation of cartographic visualization is required. That is why tools, which support cartographic presentation, should include embedded statistical modules, which – for a given data set – can calculate the number of objects presented at particular scales. This will ensure the efficiency expected by the creator of the navigation application.

4.8. Test environment

A conventional, paper map is usually prepared for the needs of printing on one, specified type of printing medium. In the phase of design, printing specifics is considered and then the production process is controlled. The issue becomes complicated in the case of the mobile system application. Such application is often installed on the large number of devices, which are unknown and unavailable for the map creator in the map creation process. The map concept for the mobile system must be correctly visualised on each of those devices. It is not possible to perform tests for all available devices. Therefore a set of representative testing devices should be selected methodologically. An example of the test environment is presented in Gotlib (2009).

5. Final remarks and conclusions

Performed analysis and experiments allow to point to specific operations, being the elements of the map designing process and to define methodological guidelines for that process. A model of developing the cartographic presentations for mobile systems has been created and tested. It may be partially useful also in the case of development of other types of cartographic presentations.

The effect of the designing process is the .xml file, which describes, in an abstractive manner, the method of presentation of spatial information in the mobile system, independent of the implementation environment.

A universal, prototype computer-assisted tool for creation of cartographic presentations has been developed within the Project; it considers the defined methodology of works. It may be used by professional cartographers and by ordinary users. It registers results of works in open formats, which allows for their utilisation in modern cartographic technological lines.

REFERENCES

Chikako K., Morishige O., 2007, *The Map Personalization Mechanizm Applying Models of Ambience and Personal Preference*. "Proceedings The 4th International Symposium on Location Based Servives & TeleCartography". Hong Kong.

Dillemuth J., 2007, *MapSize Matters: Difficulties of Small-display Map Use*. "Proceedings The 4th International Symposium on Location Based Servives & TeleCartography". Hong Kong.

Gartner, G., 2000, *TeleKartographie*. „GeoBIT“. Vol. 4, p. 21-24.
Gartner G., Cartwright W., Peterson M. P., 2007, *Location Based Services and TeleCartography* . Lecture Notes in Geoinformation and Cartography”, XXII.
Nagi R.S., 2004, *Cartographic visualization for mobile applications*. “International Institute for Geo-information Science and Earth Observation”, The Netherland
Gotlib D., 2008, *New faces of cartography – mobile cartography”*, p. 117-127, Polish Cartographical Review, Vol. 40, 2008, no 2., Warsaw
Gotlib D., 2009, *A concept of cartographic software for designing data visualization in mobile systems.*, International Cartographic Conference, Chile.
Reichenbacher T., 2004, *Mobile Cartography –Adaptive Visualization of Geographic Information on Mobile Devices*. “PhD Thesis“. Der Technischen Universität München.