A CARTOGRAPHIC PRESENTATION MODEL
FOR NAVIGATION AND LOCATION-BASED APPLICATIONS *

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ABSTRACT:

The paper presents results of research performed at the Warsaw University of Technology in Poland. The objective of introducing the Cartographic Presentation Model represented by the UML class diagram is to formalize and standardize navigation and location-based systems' design process, considering cartographic aspects. Such a process includes preparation of cartographic visualization; definition of appropriate data sources for particular geovisualization elements; definitions of factors (events), which result in modification of visualization; assurance of map content's contextual modification; and a definition of location for replaying audio communiqués, video transfers and other media.

In order to formalise this process, the author introduced and proposed the following terms: partial geocomposition, cartographic information transmission unit, cartographic event, geovisualization window, elementary geovisualization.

The author defined the genuine model using UML notation and proposed the use of xml file format; (xml files may be used for steering various navigation and location applications). Such an approach attempts to ensure the abstract description of cartographic presentation, which – to the maximum possible extent – could be independent from mobile application manufacturers' solutions. The discussed model is not a model of a geographic reality, but a model of a cartographic presentation of it, therefore in a sense, a metamodel.

1. INTRODUCTION

In order to formalize and standardize location-based and navigation systems' design process, considering cartographic aspects, we propose the use of a special cartographic presentation model, which distinguishes the most important terms used to describe cartographic presentation and to define precise relations between them. The objective of such approach is to ensure an abstract description of cartographic representation, which could be – to the maximum possible level – independent of mobile applications manufacturers' solutions.

2. BASIC TERMS

The following set of terms, proposed by Gotlib (2010), were used as basis for constructing the model:
- *Geocomposition,*
- *Partial geocomposition,*
- *Cartographic information transmission unit,*
- *Cartographic event,*
- *Geovisualization window,*
- *Elementary geovisualization.*

The term „cartographic presentation of mobile application" will be further understood as a complete cartographic transfer, defined as an end-goal function, using formal methods, with the use of a mobile navigation or a location-based application. Following Gotlib's proposal (2010), it is then assumed that cartographic presentation consists of many geocompositions. ***Geocomposition*** (the term introduced by Kozieł (2001, 2005) will be considered as an organized, coherent and complete set of geoinformation, together with a method for their presentation, displayed to the end-user in a graphical, audio or video forms, and if necessary, in all of those forms together at the same time, depending on the desired method of use. Geocomposition is, in fact, one of several possible ways of geoinformation presentation, which differ visually and are created based on demand and preferences. For example, *a day*, *a night*, *a professional*, *a simplified, a car, an aerial,* and *a tourist* geocomposition could be a made available to the end-user.

Although the user who is viewing a map in the navigation application may have an impression of continuity (with respect to the scale and geographical range), it is proposed to assume a discrete presentation model for designing purposes. This means that appropriate scale threshold (a scale series) and other boundary conditions are determined, which influence important changes of a content or a form of presentation and designing the transfer for a specified and finite number of information sets. It should be assumed that a change in the content and accuracy occurs in strictly specified scale thresholds. A change of scale, increases or

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decreases an extent of a presentation; movement of a user results in imaging the successive area (which partially covers the preceding area) and in a rotation of the presentation towards that movement, as represented in the diagram, Figures 1 and 2.

The „moving map" effect may be performed by modification of a location of a symbol, which represents a user in the background of a fixed image of a selected area (e.g. from the bottom screen edge to its 1/2 – 2/3 and jumping to a successive, „shifted" image of the area, partially overlapping the previous one (Figure 2).
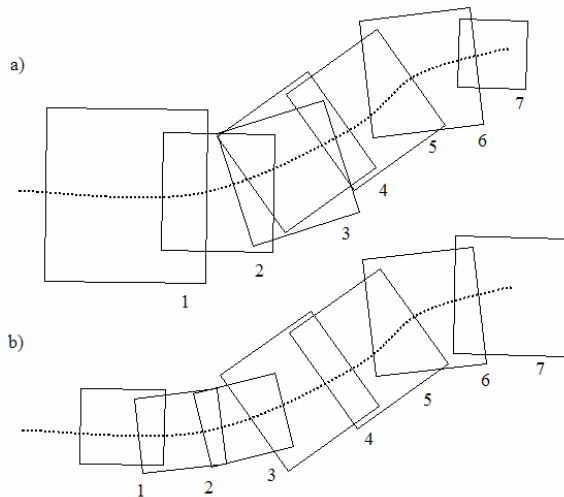

Figure 1 User movements in two periods of time (a and b) with different movement accelerations/deceleration, on the same route marked as the dotted line. The figure represents *elementary geovisualizations* successively generated by the navigation application (1-7).
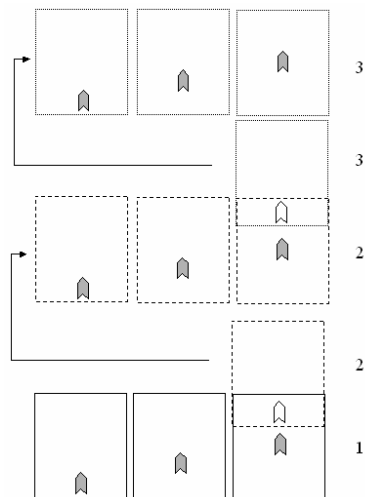

Figure 2. The process of „map moving" performed by modification of a location of a symbol which represents the user and further jumping to successive images of the area, partially overlapping the preceding images (1, 2 and 3).

As illustrated in the diagrams above, the content of the geographic database is not visualised in the form of an image at the specified scale, orientation and content, but as a set of dynamically changing images, characterised by parameters, which are often hard to be foreseen (such as in case of visualization of a data originating from „on-line" type sources and in case of an idea of a contextual change of the geocomposition content). In general it may be difficult to exactly reconstruct the same visualization by two different end-users, following the same route.

Cartographic compositions prepared for a particular scale thresholds will be further called the ***partial geocompositions.*** Partial geocompositions may differ in content and a method of information presentation, but together they create a coherent cartographic transfer within the same geocomposition. Therefore, visualization of data in a mobile system may be defined as a set of organized calls to particular, partial geocompositions. It is further proposed to specify a factor, which causes partial geocompositions or changes in their content, as a cartographic event (Gotlib 2009*). **The cartographic event** may be defined as a user interaction with a mobile application or a change of an object's motion parameters, resulting in reaction of the application and influencing a method of cartographic data presentation. The cartographic event may also result in contextual change of the cartographic presentation content. This term is not directly related to real events, but it is an element of the cartographic presentation model. Therefore, the cartographic event reflects various real events. Based on analysis of available navigation or location application's function, the cartographer should distinguish such events and then assign appropriate geocompositions and partial geocompositions to those events; such geocompositions will be called when they occur.

The following are several examples of cartographic events:

- Limiting the user's speed to 40 km/h,
- Entering/ exiting the built-up area,
- Entering/leaving the ferry,
- Driving or flying to the point of destination (or to an intermediate point),
- Achieving the destination point (or an intermediate point),
- Initialisation of searching for the specified categories of PoIs (Points of Interest),
- Initialisation of the scale changing function (image zoom in/zoom out),
- Selection of the route type (by car, by foot, by bicycle, by waters).

Selection and definition of mutual relations between cartographic information transmission units and assigning them to appropriate partial geocompositions, are the basis for the design process. ***The cartographic information transmission unit*** (CITU) may represent specified class of objects from a source database; a subset of objects of a certain class; a label generated from class attributes in a database; or an independent feature, such as a graphical symbol of a moving object (a man, a car, a plane, a ship), a georeference raster file or it may be dynamically generated, e.g a route, an arrow showing the imposed movement direction, a diagram of lanes.. When the designer assigns a cartographic symbol to the *CITU*, generate a corresponding legend item.

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Another term, which is used in the model, is the geovisualization window. **The geovisualization window** is defined by specification of the image resolution (in pixels), the screen diagonal or its fragment, used for displaying a map and the type of visualization: 2D, 2.5D, 3D. Thus the geovisualization window delineates an elementary fragment of the geocomposition, which the user may see at the observed time. That fragment of the geocomposition will be referred to as the **elementary geovisualization** within the presented model. The geovisualization window may be shifted and rotated, what generates successive elementary geovisualizations (Figure 1 and Figure 2). If the geovisualization window is projected on the surface, we may imagine the trance marked within the terrain area, which defines the extent of the elementary geovisualization. The term of the geovisualization extent may be useful for controlling various functions of the navigation application.

The specified geocomposition may be viewed through a set of many geovisualization windows, what is a result of the specific features of mobile applications, which are often used on many mobile devices of various display parameters. Some of those applications also allow for simultaneous presentation of the terrain at two scales and two modes. For example, besides the standard navigation mode, a preview map mode is available at the smaller scale. Therefore, cartographic presentation should be adjusted for viewing it through many geovisualization windows. The elementary geovisualization is not determined only by parameters of the geovisualization window, but also by cartographic events, which result in contextual modification of the content of the cartographic transfer.

Using the above terms and relations between them it is possible to completely define the transfer of cartographic information, to be performed by a mobile application. For that purpose it is necessary to define the formal cartographic presentation model for navigation systems. The model should be designed in such a way that its use allows for consideration of the most important features of the mobile cartographic presentation, in particular, the contextuality of the transfer of cartographic information.

3. UML CLASS DIAGRAM

Research, analyses and considerations performed by Gotlib (2009, 2010) allowed for defining the cartographic presentation model, presented by means of a UML class diagram in Figure 3. According to the presented diagram, the cartographic presentation (*CartoPresentation* class) consists of at least one geocompositions (aggregation relationship) (*GeoComposition* class), and each one consists of at least one partial geocomposition (*GeoCompPart* class). The geocomposition may be related to another geocomposition (the recurrent relation). For example, in the case of a mobile systems, which are able to simultaneously display two visualization windows, the geocomposition developed for the needs of viewing data at a small scale may be related to the main geocomposition for medium and large scales. The requirement would not allow the use the viewing window without the main visualization window.

The cartographic information transmission unit (*CITU* class) is a basic element of a geocomposition. The *Type* attribute allows for distinguishing various types of cartographic transfer units, such as geometric, raster, sound, textual, labels, photographs, video sets and special types. The *CITU* may take part in recurrent relationship (with another unit). Two possible relationship may be distinguished:

- Having the parent unit,
- Relationship with another entity, without which it should not be used.
-

By implementing the first relationship the designer may create the hierarchy of the *CITU*. A well defined hierarchy simplifies the creation of the next partial geocompositions or derivative geocompositions, in particular as a result of shortening their descriptions (the "inheritance" mechanism). Implementation of the second type of relationship enhances consistency of a composition. For example, the *CITU* of the *sound, video, photograph* or a *text* type should be usually linked to the *geometry* or *raster* type CITU. Such link makes it possible to identify categories of objects in space, with which a user interaction, while using the system, should produce a desired sound, video, picture or description.

In the design process, a cartographic information transmission unit should be assigned to a partial geocomposition (relationship between *CITU* and *GeoCompPart* classes) and specify a cartographic symbol, appropriate for the given scale level (using the *CartoSymbol* class). In some geocompositions (for example prepared for blind people) the cartographic symbol is not assigned. However, identification of both corresponding elements is required in any case, i.e. a partial geocomposition and a *CITU*. The relationship, together with simultaneous assignment of the cartographic symbol means that the appropriate legend item is defined for geovisualization. Such information is recorded within the UML association class) presented in the diagram (*LegendItem*). At the design stage, such solution allows for defining additional features of the discussed relationship – hierarchy of displaying a given geocomposition element and displaying priorities in the case when graphic conflicts occur between objects.

As a result of the above, the same *CITU* may be presented by various cartographic symbols in various partial geocompositions (i.e. at various scales). The way of defining cartographic symbols itself is independent from the cartographic presentation model. The symbol definition may be limited to specification of its identifier, from an appropriate set of symbols. Possibly, it allows for maintaining a highly abstractive and universal description of a cartographic presentation. As a result, various navigation software developers may utilise various symbol libraries, created in various ways, but compliant with the same set of symbols. The identifier from that set is the only connecting element. However, it is possible and recommended to present a complete definition of the cartographic symbol by assigning the appropriate value of a *Definition* attribute, which may be performed in the form of SVG text (or another, well known and widely approved standard).

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In the diagram the *CITU* class is related to the *DataSource* class, which should be used for storing rules of data acquisition, for the needs of cartographic presentations, from source databases. The objective is not to automate data import, but it is an indirect form of defining the identity and conceptual meaning of the CITU. It is proposed to record the definition in the form of a SQL command, as the value of the *SQLStatement* attribute. And the *IDDataBase* attribute should be used for recording the identifier of the database, from which data is extracted (the cartographic presentation, as well as the entire mobile application may use several data sets).

The user may view the cartographic presentation (*CartoPresentation* class) through the geovisualization window (*VisualizationWindow* class), what has been reflected in the model, by specifying the association relationship between those classes. The *VisualizationWindow* class has attributes, which define the display parameters and the way of data viewing (2D, 3D etc.). As a result, the developer may record information concerning geovisualization windows, through a definition of display parameters for the final set of devices, which could be used to correctly display the presentation (dedicated displays). The specified geovisualization window may be also used for viewing many partial geocompositions (*GeoCompPart*). Partial geocompositions may be viewed through many geovisualization windows. As a result, following that relationship the possibilities to view a map at given scales may be limited to selected geovisualization windows only. For example, we may imagine the designed limitations, such as: selected partial geocomposition for the scale of 1:20 000 should not be displayed using the geovisualization window smaller than 2 inches, with the resolution 128x160 pixels (below which, some objects may not be visible). The entire cartographic presentation allows a designer to use a specific set of visualization windows for geocompositions. For each defined relationship between the *VisualizationWindow* and *GeoCompPart* classes, an abstract elementary geovisualization exists, which is represented by the *EGVTransition* association class. It allows a developer to describe a possibility to rotate an elementary geovisualization frame by a specified angle – under the influence of a specified cartographic event, or to set it according to a specified azimuth value.

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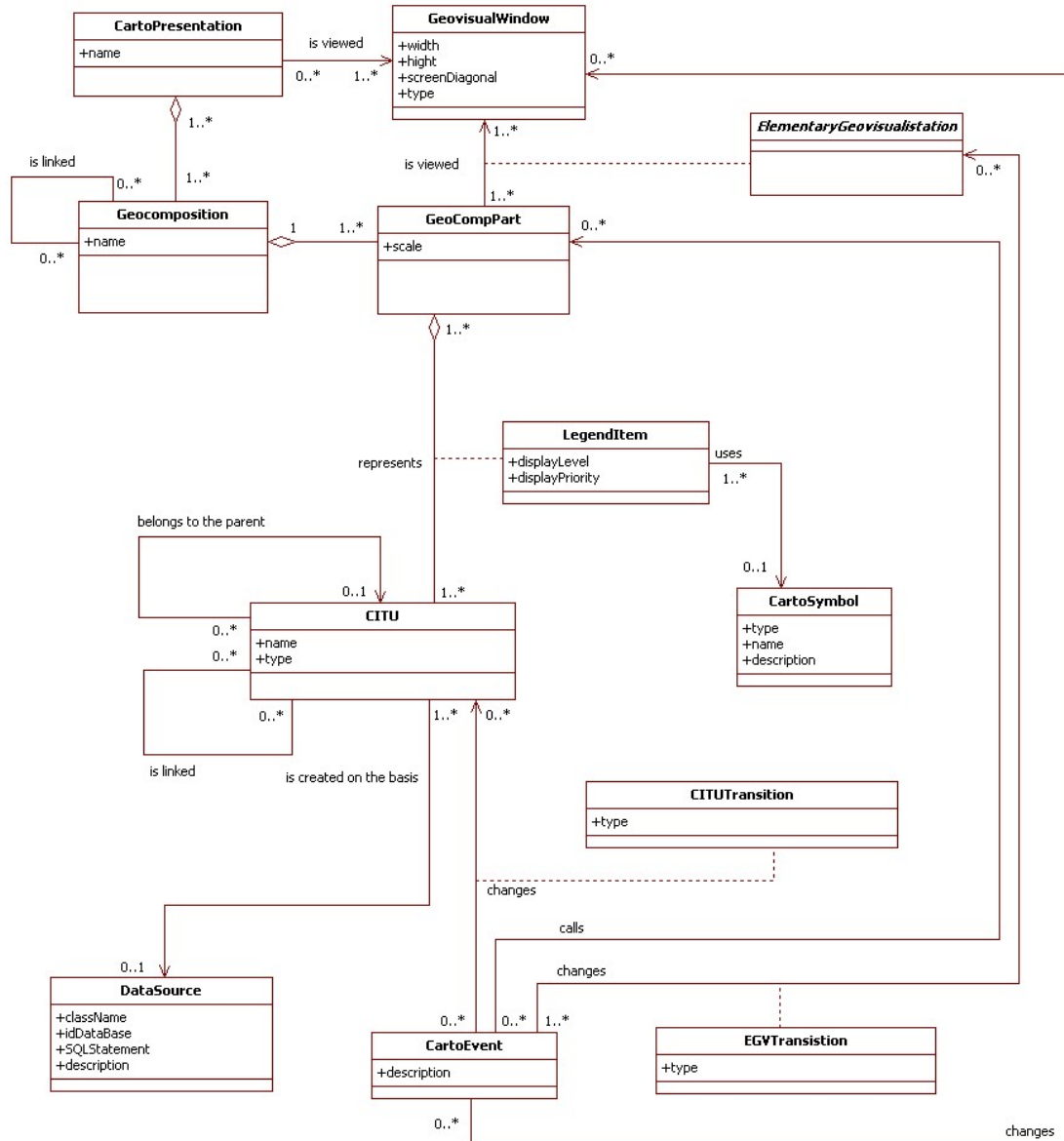November 15-19, 2010 Orlando, Florida

Figure 3. UML class diagram which defines the method of description of a cartographic presentation for navigation applications.

Cartographic events, which may result in rotation of an elementary geovisualization, are defined within the *CartoEvent* class. That class also represents cartographic events which result in modification of a geovisualization window (e.g. from 2D to 3D mode) and events resulting in modification of a partial geocomposition (e.g. such events which zoom in or zoom out of the map). An event may also result in a change of the whole geocomposition (e.g. from *day* into *night* one), by calling the appropriate partial geocomposition. Those relationships are many-to-many type, meaning that e.g. the "Speed change" event may cause more than one partial geocomposition (e.g. partial geocompositions which are included in various geocompositions). On the other hand, the partial geocomposition may be called by many events. The developer of the cartographic presentation does not make the decision about the way in which those changes are introduced, but decides whether they are required for the proper cartographic information transfer.

In a case when it is necessary to design the influence of a specified cartographic event on a state of the CITU or on the status of the elementary geovisualization, it is possible to utilise the association classes *CITUTransition* and *EGVTransition*.
For example, in the first case, the developer may define the change, as:

- Turn on/off the display of a cartographic symbol,

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- Graphical weakening of the cartographic symbol,
- Graphical strengthening of the cartographic symbol,
- Selecting of the other cartographic symbol.

In the second case.g. the following functions may be defined for the elementary geovisualization: rotation by 10 degrees, setting the map frame to the azimuth of 180 degrees, shifting by 800 m (see Figure 1 and Figure 2).

3. IMPLEMENTATION

Implementation of the presented model can be carried out by using of special cartographic applications. Related proposals were, among others, defined by Gotlib (2009). It is possible to perform implementation of both, in a form of a relational or object database, and in the form of *xml* files. A small fragment of an example xml data file below (Figure 4) relates to a complex definition of a structure, currently in implementation phase.

```
<CartoPresentationFile
      xsi:schemaLocation="http://http://www.zk.gik.pw.edu.pl/MobileC
      arto/MPKSN.xsd">
   <CartoPresentation>
      <CITU>
         <ID>1</ID>
         <Type>geometry</Type>
         <Name>PoI</Name>
         <IdParent>0</IdParent>
      </CITU>
   </CartoPresentation>
   < CartoPresentation >
      <GeoCompPart>
         <ID>2</ID>
         <ScaleLevel>1000</ScaleLevel>
         <IdGeoComp>1</IdGeoComp>
      </GeoCompPart>
   </CartoPresentation>
   < CartoPresentation >
      <GeoComposition>
         <ID>2</ID>
         <Name>Day-Standard</Name>
         <Use>1</Use>
      </GeoComposition>
   </CartoPresentation>
   <CartoPresentation>
      <CartoEvent>
         <ID>2</ID>
         <Description>Speed>90 km/h</Description>
      </CartoEvent>
   </CartoPresentation>
   <CartoPresentation>
      <LegendItem>
         <IDGeoCompPart>2</IDGeoCompPart>
         <IDCITU>46</IDCartoUnit>
         <DispLevel>1</DispLevel>
         <Prioryty>1</Prioryty>
      </LegendItem>
   </CartoPresentation>
   ...
   ...
</CartoPresentationFile>
```

Figure 4. Fragment of the *xml* file representing cartographic presentation for a mobile application.

The relationships between a cartographic application (CVS) based on the model proposed above and components of the navigation system is presented in Fig. 5. Basing on the GIS database (GIS

DB) or on information from the converter of the navigation system (CoNVerter – CNV), the CVS can generate a list of cartographics information transmission units. After designing cartographical presentation in the CVS editor, information can be transferred by means of the xml format to the visualistation module of the navigation application (VM) and/or the CNV. In the latter case information may be used for controlling the conversion process in order to obtain the appropriate cartographic presentation (if the converter designer decides to utilise those data).
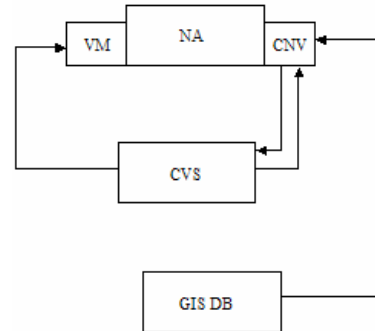

Figure 5. Relationships between a cartographic application (CVS) and components of the navigation system. NA – a navigation application, VM – a visualization module of the navigation application, CNV – a converter of the navigation application, GIS DB – a source GIS database.

4. CONCLUSIONS

Detailed discussion of all features of the presented model and ways of its implementation is not possible due to limitations of this paper. Appropriate details will be presented in follow up papers. The most important possibilities resulting from practical implementation of that proposal are mentioned below. Using the proposed model, a developer-cartographer may define:

- a diverse range of a map content for various sizes of mobile displays,
- a diverse range of a map content for a preview window and the main window, in a coherent way, within one geocomposition,
- a diverse range of a map content at different map scales,
- a diverse range of a map content for different modes of map viewing 2D, 2.5D, 3D,
- a permissible mode of viewing given cartographic presentation: 2D, 2.5D, 3D,
- geocompositions which have a raster image in the background (e.g. an aerial photograph) or preview from a camera,
- a geovisualization legend,
- changes in a scope of a map content, which should be introduced as a result of various users' behaviours, such as: change of movement speed, change of movement direction, entering into the specified type of terrain, approaching the destination point,
- various ways of geovisualization of the same data within one mobile application,

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- mutual relationships and connections between various cartographic geocompositions (e.g. day and night),
- a angle of rotation or orientation of a map where a user changes the direction of motion or changes the course settings,
- a range of supported thresholds of a scale (which may be different for different compositions),
- linking a selected category of objects to: audio messages, text descriptions, video,
- a way of acquiring geovisualization content from a source database,
- relationships between cartographic information transmission units (CITU) , including hierarchy

Based on the proposed approach not only it is possible to define typical cartographic presentation dependent on a graphical terrain representation, but also the geoinformation transmission in the „navigation window without a map" mode or systems for blind people.

Therefore, the presented model allows for formal, practical describing of all features of cartographic presentations, which are characteristic to navigation applications and systems, which are described in previous sections.

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