# Mobile GIS: Attribute Data Presentation Under Time and Space Constraints

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**Abstract.** An ontology-based generalization scheme is presented with specific reference to object attribute data subjected to space and time constrained extraction and presentation. The method is expected to be of value in mobile GIS for providing travelers with additional spatial information while moving. The space constraint is given by the boundary of an object-specific area of information relevance. The time constraint is given by the number of time units available to present the information as a function of the speed of travel and the spatial distribution of objects. An algorithm for changing the duration of the attribute data presentation is presented. A geodata-ontology is used to specify meaningful transitions betweeen levels of generalization.

## 1 Introduction

The increasingly popular navigation systems based on small mobile computers (PDAs) equipped with a GPS may be viewed as mobile GIS implementations since they contain both road map data with attributes and network algorithms for findings best routes. Viewed as a GIS, however, the functionality is very specialized since the ability to provide other spatial information than what is relevant for the way-finding is rather limited. Several studies have examined the potentials of map reading from mobile devices and how this is different in nature from use of traditional paper maps (see f.ex. [16]). To date, however, few papers have described efforts to further utilize the potential ability of the mobile GIS to provide elaborate attribute-type information about any object that a user interacts with while moving around. Frank et al see the process as a transformation of the traditional GIS into a Location Based Service by providing mobility, distributiveness and egocentric awareness [5]. They further describe a system that enables a user carrying a PDA equipped with a GPS and an orientation sensor to get access to the attribute data stored for a feature of interest by standing and facing it. The general problem of selecting the physical object for which to receive information in a given spatial context (equal to the human action of pointing) has been examined by Egenhofer [1]. Current solutions are still mostly of an experimental nature and assume availability of special equipment such as directions sensors or advanced pointing devices.

It is reasonable to conclude that the potentials of the GPS-PDA to act as an advanced location-based information system are acknowledged but still not examined in-depth. Nevertheless, some systems restricted to confined locations such as cultural

M.A. Rodríguez et al. (Eds.): GeoS 2005, LNCS 3799, pp. 234 – 241, 2005.

or entertainment sites have been implemented in practice. IST describes how GPS-enabled city guides are already used in the travel industry and argues that especially the "culture and history travel market" will be able to benefit from a strategy towards location-sensitive presentation of object information [7].

## 2 Presenting Attribute Data while Moving

The focus of the current paper is the extraction and presentation of GIS-attribute data while moving. Furthermore, focus is put on the situation where a) the user cannot interact directly with the device or point to any location (e.g. because he or she is engaged in driving) and b) the user wants relevant attribute information to be presented more or less continuously while moving. This obviously creates a need for rethinking the traditional view of the attribute database as a container of numbers or small bits of text that may be read of the screen with no time limit given for the reading process. A relevant type of information to be considered here is sound recordings of a given duration attributed to each object. Furthermore, it is necessary to address the issue of generalization with focus on the attribute data.

The movement of the GIS-PDA during the process subjects the extraction and presentation of each bit of information to space and time constraints. The primary objective is to present the traveler with timely and complete information within the time frame given by the travel speed. The time constraint can be viewed as the number of time units available to present the information as a function of the nearness of neighboring features, the speed traveled by the audience and possibly some stated preferences concerning the desired level of information. It is important that the degree of data completeness is known. At constant speed, all information related to a specific generalization level at a given location should be presented – not a random selection. It is therefore necessary to reduce the duration of the information message if the speed and object density do not allow presentation of all information.

The space constraint is given by the boundary of the area within which the information about a specific object is relevant to a specific audience. The attribute presentation should therefore take place within this zone. In some cases, depending on the travel speed, the time required for presenting the information could take up a travel distance that far exceeds the zone of relevance. A reduced duration of the information message – if possible – is required in this situation also.

Three approaches to data generalization aiming at reducing the amount of attribute information for presentation are described below.

**Selecting a more generalized data layer.** Using this strategy, the ability to present attribute information on different levels of generalization is based on the existence of several data-layers within the mobile GIS. These must be of varying levels of generalization and all cover the area of movement. Traditionally, the map generalization process involves a number of techniques for changing the appearance of graphic objects in the map, e.g. simplification, enlargement, merging and selection [7]. The aim is to produce a map that is targeted to a specific presentation scale and possibly also to a specific purpose and user group. A number of methods for this have been described in literature but mainly targeted towards traditional paper maps. In the digital domain, Kulik et al [8] describe an algorithm for the generalization of line segments for use with mobile devices. This approach is based on – or driven by – a formalized ontology. According to Weibel, a main difference between the conventional and the digital context is that, "in digital systems, generalization can affect directly the map data and not the map graphics alone" [14]. Also with reference to digital systems, Weibel & Dutton argues that generalization has assumed a wider meaning as "a process which realizes transitions between different models representing a portion of the real world at decreasing detail, while maximizing information content with respect to a given application" [15]. The main objective of this model generalization is controlled data reduction for various purposes and serves the purpose of deriving datasets of reduced accuracy and/or resolution. It is also stated by Weibel & Dutton that the generalization process could be replaced by a strategy for producing multi-scale databases that "integrate single representations at fixed scales into a consistent multiple representation" [15]. In this way, the different generalization levels are constructed initially in the database.

**Selecting a subset of objects.** A suitable generalization may also be obtained by selecting a set of objects from the detailed map. This strategy is actually a part of the traditional methods for map generalization. It is treated separately in this context because it requires only one data layer within the mobile GIS. Furthermore, it requires the existence of attribute data that characterizes the individual object in terms of importance within a given thematic domain. Examples could include buildings that are interesting in the context of a specific historical period. Also objects that share a certain property or functionality could be selected. The result is a dynamically created data layer with a reduced amount of attribute data. This generalized data layer is created entirely based on attribute values and the location of the objects is therefore irrelevant for the selection process.

**Selecting object class information.** The above described generalization strategies are basically seeking to identify a suitable set of existing geo-objects within the mobile GIS. This is in accordance with the traditional role of the GIS as a provider of information concerning specific objects linked to specific locations. An approach with a different angle will be discussed briefly here. In order to achieve a required reduction in data a shift is made from object attribute data to object *class* attribute data. In other words a shift is made from location-specific information to 'encyclopedia-type' information. The object class attribute data are not linked to a specific geographic location. It consists of information that is common to a subset of objects within a GIS-layer no matter their individual location.

The described generalization strategy is seen as particularly useful in a situation where a subset of objects with similar properties within a given domain is located in a spatial cluster. Take as an example a set of trees of a specific species located close to each other. This will result in a situation where the information relevance areas of the objects are partly overlapping indicating that they may be perceived as a group when traveling through the area. In this case a pre-established object class containing general information about the tree species may be applied. This approach goes somewhat beyond the traditional definition of a GIS and it would require additional data structures to implement an object model that includes generalized class information. This is further discussed in the next section on geodata ontologies.

### 2.1 A Geodata Generalization Ontology

A mobile GIS to be used on the move could apply one or more of these generalization strategies for adjusting the amount of attribute information to given time constraints. In many cases, however, geo-data of different generalization levels do not constitute meaningful substitutions for each other even though they cover the same area. The adjustment process requires that knowledge about meaningful transitions is present within the system. The set of "legal" vertical moves between data layers of different generalization levels is regarded as an ontology of the system. The term ontology is used here to denote a formal specification of the concepts and relationships that can exist within a certain domain and is able to capture aspects of the semantics of this domain.

The use of ontology in software systems has been proposed in several studies, primarily within the field of information processing. Raper states generally that the new generation of digital geo-representations makes it possible for each geographic information scientist to design their own ontologies for the task at hand [11]. Rodriques & Egenhofer describe the use of ontology comparison in the process of retrieving and combining information that resides in different repositories to identify any differences in data definitions [13]. Fonseca *et.al.* argue that ontologies support the creation of conceptual models and help with information integration and propose a formal framework that explains a mapping between a spatial ontology and a geographic conceptual schema [3]. Moreover, Fonseca et al. describe a comprehensive ontology for geographic information aimed at improving data integration at different levels of details – a process that also involves object generalization and specialization [4]. Another example of ontology supported data extraction is provided by Møller-Jensen who uses ontology information represented in semantic networks to predict the textural pattern of urban objects in satellite images for semi-automated classification purposes [10].

In the present context of mobile GIS, the ontology is used as an active system component that provides guidance for the generalizing process regarding the attribute data. The process of continuously selecting and presenting relevant data layers in order to comply with the given time and space constraints is based on an examination of the ontology properties. These ontology properties are conveniently defined using semantic networks defined as knowledge representation schemes involving nodes and links - the nodes constituting objects and the links constituting relations between objects [6],[12]. In the current context the ontology objects represent data sets included in the system – either existing, static GIS layers or data sets that may be created dynamically by an attribute selection process. The object relations of the generalization ontology must include the following types: a) *is_a_spatio-thematic_generalisation_of* and b) *is_a_conceptual_generalisation_of*. Type a) relations exist between two ontology objects that represent data sets and indicate that these may be substituted by each other during the generalization process. Type b) relations exist between a sub-object that either represents a data set or a class definition and a super-object that represents a class definition. They indicate that a generalization can be achieved by applying the information associated with the super object.

The set of vertical moves that is meaningful and relevant to a specific user may be seen as an ontology that exists in parallel with the system ontology and reflects the specific thematic preferences of the user. Successful application of a mobile information system requires a high degree of similarity between the system ontology and the user ontology. Stated more informally, the information presented on various generalization levels should be relevant and meaningful to the specific user. This could be achieved by allowing the user to define properties of the system ontology given a specification of the data that is included in the system, or, alternatively, by allowing the user to choose between different pre-defined and theme-specific ontologies.

# 3 Algorithm and Prototype

This chapter describes the proposed algorithm for the process of adapting the attribute data presentation to a given speed. While it may be possible to identify strategies for a purely graphical 'on the fly' simplification process based on a set of rigid rules, e.g. for removing close lying vertex points, a similar approach is not possible with attribute data. Any process aiming at automatically shortening text messages would be of a completely different and complex nature and subject to a number of problems especially if the attribute information is taking the form of sound recordings.

In the proposed algorithm, therefore, the dynamic generalization process is equal to the process of choosing between data sets of different levels of generalization. Such datasets – generalized in accordance with the guide lines discussed above and providing a data hierarchy that is compliant with the user ontology - are expected to be provided in a separate work flow. An alternative development path, discussed e.g. by Kwan & Shi [9] is the application of wireless systems that streams the necessary data to the PDA in real time, responding to specific data requisitions from the PDA.

The discussion in chapter 1 and 2 is formalized by making the following definitions:

The *R-space* (relevance space) is defined as a static buffer zone surrounding an object within which attribute information for the object is of relevance to the moving audience. Visibility analysis based on digital elevation models and line of sight analysis may be applied in a more advanced stage to derive the zone. In some special cases it could be relevant also to focus on other properties than visibility, such as the spatial extension of sound or smell from an object. For the current system, however, standard fixed-width buffer zones have been created around each object to provide an indication of the R-space.

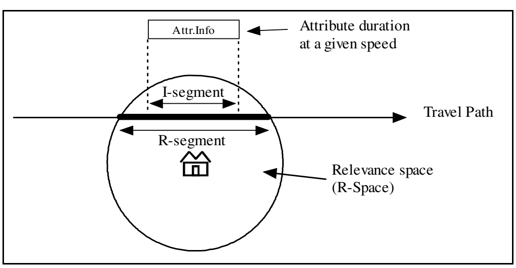


**Fig. 1.** I-segment indicates the duration of the message while R-segment indicates the section of the travel path where the information is relevant

The *R-segment* (relevance segment) for an object is defined as the projection of the R-space onto the path that the traveler is currently following, (see figure 1).

The *I-segment* (information segment) for an object is defined correspondingly as a segment of the current path with the following properties:

- the halfway point is equal to the halfway point of the R-segment of the object
- the length is equal to the distance covered during the time it takes to present the attribute information given the current level of speed.

The I-segment must therefore be computed dynamically based on the current speed of travel, see also figure 1.

Overlapping I-segments at a given speed indicate that there is not enough time to present all attribute information at this level of generalization. In some situations, the I-segment could be considerably longer that its corresponding R-segment. This would indicate a situation where the traveler would have "passed the object long ago" when the potential attribute presentation ends. It seems reasonable to either suppress the presentation in this situation even if there is sufficient time for the presentation or alternatively to select a more generalized level if available. The latter strategy is implemented in the current prototype.

Following the discussion above, three strategies for attribute data generalization are considered in the prototype. Strategy 1 and 2 handle implementation of the spatio-thematic type of generalization while strategy 3 handles the implementation of the conceptual generalization:

1. Generalize by selecting a subset of all objects. The selected objects should be characterized as important within a specific thematic domain.
2. Generalize by moving to a previously established less detailed GIS-layer with thematically coherent attribute information as defined by the system ontology.
3. Generalize by applying information contained in a thematically coherent object class, or – in other words – provide the user with general encyclopedia-type information. This information is geocoded on-the-fly by linking it to the smallest polygon that covers the R-spaces of a selected set of GIS-layer objects. The polygon constitutes the R-space of the class attribute information and it is used by the algorithm to position the I-segment and hence to decide whether there is time enough to present this information. The objects that are used to define the polygon must be characterized by having identical values for an attribute value that specifies the object class. Moreover, the objects must be clustered together in a way that makes their R-spaces overlap as discussed above. The coding of the algorithm is relatively straightforward and pseudo code is provided below. Note that the word "level" means "level of generalization" in the pseudo code:

1. Retrieve the current speed and location of the traveler
2. Choose the most detailed level and all objects within this level
3. Generate R-segments by projecting the R-layer buffers of the current level to the expected travel path corresponding to a selected time period (see figure 1).
4. Generate I-segments centered on the R-segments by computing the length necessary to present the attribute information.

5a. If no I-segments overlap: (there is time to present all information at this level)
    compare I and R lengths:

if (I-segment >> R-segment):
try selecting higher level data (based on system ontology), goto step 3
otherwise
present attribute information from the current level
5b. If I-segments overlap: (there is not enough time for all information )
try selecting higher level data, (based on system ontology), goto step 3
- If no higher level data can be found in step 5: pass by the objects without providing any information
6. If tour not ended: goto step 1

## 4 Discussion and Conclusions

The prototype software is developed for experimentation purposes and is currently in a 'laboratory' stage. The real-time nature of the attribute presentation process creates some problems for documenting its behavior. The software reports the selected speed, the computed start and ending points of attribute information, as well as the information itself. The expected future travel path (EFTP) is not given much attention in this study, although the ability to estimate this for some limited distance at any time during the travel is, indeed, important for the proper selection of attribute data. The required length of the EFTP depends on the speed of travel and the duration of the potential up-coming attribute messages. Computing the EFTP becomes easier if the mobile GIS is used also as a navigation device and providing the user with directions. The use of probabilities for route selection based on current direction and type of road etc. will be necessary if no route is given a priori.

The above discussed issue of selecting the specific generalization strategy is important, if the ontology and data availability allow for a choice between several options. It may, for example, be possible – at a given speed – to select both a subset of objects within the same layer and a more generalized new layer to reduce the duration of the information. This functionality is not handled by the prototype at this stage, since all test runs are made with only one suitable generalized data set. It would be reasonable to assume that user preferences in this case would be related to the specific type of data. As an example, the user may prefer general class information about the vegetation species as a generalization of tree objects, while preferring the spatio-thematic generalization of building objects into buildings objects of historical interest. If this is the case, it will be necessary to expand the ontology definitions to include these preferences. Following a similar line, it could be argued that a user may sometimes prefer a more generalized level of information than what is potentially possible at the current speed. This is not an ontology issue but rather a question of allowing the user to control the system behavior by having all potential attribute information compared to a certain user defined threshold that excludes the detailed information.

To conclude more generally, it would seem as if the well known concept of geographical information systems is easily depicted in a mobile information system context. The close association between attribute data residing in a database and graphical objects on the map is what defines the GIS and provides its potentials. It should therefore be clear that presenting these attribute data in a mobile context could also be highly beneficial. The high amount of existing spatial data that would be of interest to different segments of travelers is also an argument for further work towards making these data available in mobile systems.

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