NEW TOOLS FOR MULTIPLE REPRESENTATIONS

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Abstract
Multiple representations make up an essential part of Geographic Information Systems. They not only require new database models and structures. They also require new tools within the user interface. The aim of this paper is to show what kinds of new tools are necessary to deal with multiple representations.

Introduction
Multiple representations make up an essential part of Geographic Information Systems (GIS): In cooperative GIS, each cooperating user needs its own point of view with its own semantics and its own abstraction to represent phenomena of the real world. Complex applications use several representations with different levels of details during the process, see for example exploratory data analysis [Yuan and Albrecht 95] or landscape and urban planning [Timpf et al. 92], [Langou and Mainguenaud 94]. Even for a great variety of simple geometric applications, it is necessary to store multiple representations of the same data in order to facilitate the efficient computation of operators [Günter 89]. Nowadays, spatial databases are very similar to maps, i.e. only one representation at one scale is available. These databases are satisfactory only for GIS with one type of user and for a single application.

In general, different levels of detail are needed when dealing with spatial data [Minsky 85]. A single spatial representation at the maximum level of detail is not satisfactory for the user. Besides, there are several data sources (geographic databases) with different resolutions, times, accuracies, etc. Unfortunately, current systems lack the ability to deal with multiple representations in their database or in their visualisation [Buttenfield and Delotto 89].

In the remainder of this paper we present what we understand by multiple representations and restrict ourselves to multi-scale representations that are important for cartographic applications. Then we introduce some new tools that can handle multi-scale representations and therefore improve interaction with multi-scale GIS.
What are multiple representations?

We understand by multiple representation that the same geographic phenomenon or entity is multiply represented under different aspects within a single system. These aspects may be:

- **time**: time of representation
- **accuracy**: relationship between a measurement and the reality which it purports to represent
- **resolution**: the smallest entity which can be represented (geometric resolution) and the degree of detail of semantic attributes (semantic resolution)
- **precision**: degree of detail in the reporting of a measurement
- **scale**: conveys the needed level of abstraction of the phenomenon
- **spatial data model**: model for description of spatial data (e.g. raster or vector)
- **application**: type of application - this also determines the concept of space.

The list is not complete, but it shows very well the complexity of the problem. The **main sources of problems** with multiple representations can be divided into two groups. The first group is concerned with storing, handling, and updating multiple representations in databases. The second group relates to the visual rendering of the data on a screen, that is accommodating the information on a bounded display so that it is visible. The problems that arise are mostly connected to transaction management, redundant databases, updates of the database, performance time, storage considerations, missing concepts of how to handle multiple representations etc. To avoid these problems, most GISs use only one type of data in their databases and store a single predefined rendering of the data. In that respect spatial databases are very similar to maps, i.e. only one representation at one scale is available.

In this paper we concentrate on multi-scale representations, which are a subset of multiple representations. Multi-scale representations are those representations that have different levels of detail or levels of abstraction. A geographical database does not formally include the notion of scale but it seems important to associate precision, accuracy, and resolution with the notion of scale commonly associated with a map [Goodchild 91] [Müller et al. 95]. However for this paper we assume that a multi-scale database exists and analyse what new tools are required in this multi-scale environment.

News tools for handling multiple representations

Multi-scale representations not only require new database models and structures [Timpf and Frank 95] [Devogele and Raynal 96] [Jones 91] [Rigaux and Scholl 95]. They also require new tools within the user interface to handle this multiplicity and to effectively work with several representations. We have identified five different tools for multi-scale representations. The first four tools (zoom, browse, select, and pan) require that existing tools change, the fifth tool (update) is new at the user interface level.
Zoom Tool [Frank and Timpf 94]

Zooming is a highly used operation in GIS. Any time the user wishes to change either the visible range of data on the screen or its detail it is necessary to zoom. Zooming can be done in three different ways: it can change the viewing window to accommodate a larger area, it can give more detail on the same area and it can change the content of the screen, showing other data of the same area.

The **graphical zoom** only enlarges the viewing window. After zooming, objects are larger but less objects are in the field of view.

The **content zoom** gives more content information, it therefore adds thematic information.

The **intelligent zoom** give more information (more detail) at a different level of detail when zooming in.

The difference between existing tools ([Robertson 86], [Furnas 86]) and intelligent zoom is that the level of detail is changed in the representation (see figure 1).

![figure 1: Zoom Tool](image)

The idea is that the user will be able to choose between these three different ways of zooming, depending on what he has in mind.
Select Tool

Multiple representations allow to navigate between representations, but this navigation must preserve the selection of the user. The selection tool must be able to propagate the selection in one representation to another representation, probably to a different window. For example, in figure 2, if the user selects three objects (two cross-roads and one section), the select tool must be able to select objects which represent the same part of the real world in a more detailed representation. This is especially interesting when working with different windows. At the moment, when changing the representation or the window, all previous selections are gone - the user is lost.

![figure 2: Select Tool](image)

Browse Tool

The multi-representation browser enables to simultaneously consult the semantic information that comes from different representations. Indeed, this information can be complementary, and applications need information from all representations. This is the extension of the selection tool to the attribute domain.

Panning Tool

The panning tool must also improve, users want to pan over one representation and find themselves in the same area in another representation. This is necessary for the preservation of the focus and serves a similar purpose as the selection and the browse tools - the user must not get lost or loose the information already given in another
representation. It is an important tool and adheres also to the ‘WYSIWYG’ philosophy. This means that if the user pans, he pans in all representations at the same time.

**Update Tool**

In a multi-scale data-structure information transfers between representations become possible. For the process of updating this means that it is possible to propagate an update performed at some detailed level to a less detailed level [Kilpeläinen 95]. This is not only important for the process of updating the whole database but also for the user interface. In the first case, the most detailed level is updated and the changes propagate through the less detailed data-sets. In the second case, a user selection and change (either of colour or even of geometry) may be propagated through all lesser detailed representations. This tool is therefore a prerequisite for the selection tool. The difference between the first and the second case is the permanence of the action. When updating the database the change is registered, when using the user interface the change is temporary.

**Conclusion**

The result of this paper is a description of multiple representations and some of their tools. These tools are essential to handle multiple representation, especially multi-scale representations. However, we find that these tools could not be implemented in current spatial databases. Even if the database features different representations of the same geographic phenomenon, those representations are not linked. It is imperative that representations be linked [Devogele et al. 96] for example by schema integration ([Spaccapietra et al. 96], [Nyerges 89], [Stephan et al. 93]) or spatial data matching [Lemarié 96]. Attempts to do so for a very specialised application, namely wayfinding in road networks, has proven encouraging ([Timpf et al. 92], [Car 96]). It is nonetheless necessary to look at the tools that multiple representations would require. Their design and application have a large impact on the design of databases for multiple representation.

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**References**


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