Managing Geo Data for Location-based Services – The Hybris Framework

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Abstract. Even though geo data are getting more and more widely available nowadays, they often do not meet the requirements of location-based services concerning structure, content and format. Often, an application provider thus has to modify or adapt geo data. Moreover, applications still have to deal with the position capturing process and the sensor fusion task. In this paper we present the Hybris framework that provides a geo data authoring environment and position reasoning services that significantly simplify the development of location-based services.

Keywords: Location-based Services, Geo Data, Positioning, Spatial Reasoning

1 Introduction

Geo data form the natural resource for location-based services. Geo objects describe the world in terms of natural, artificial and virtual entities that cover the earth's surface. Important functions such as displaying maps, maintaining points of interests (POIs) and navigation strongly rely on the quality of geo data.

Managing geo data becomes a more and more difficult tasks. A huge variety of sources are available that range from land survey data (e.g. ATKIS), freely available geo data (e.g. OpenStreetMap), privately assembled data such points of interests collected with the car navigation device or GPS tracks stored in GPS loggers. These data have different characteristics concerning quality, structure and contents, thus data not only have to be imported from different formats, but have to be corrected, fused, enriched and finally integrated into a data repository.

In this paper we present the Hybris environment. It is built to collect and manage geo data for location-based services; it contains a component to access positioning systems and provides a location reasoning mechanism.

2 The Hybris Environment

The Hybris environment connects the components *External Geo Data*, *Authoring, Positioning* and *Applications* as illustrated in Fig. 1.

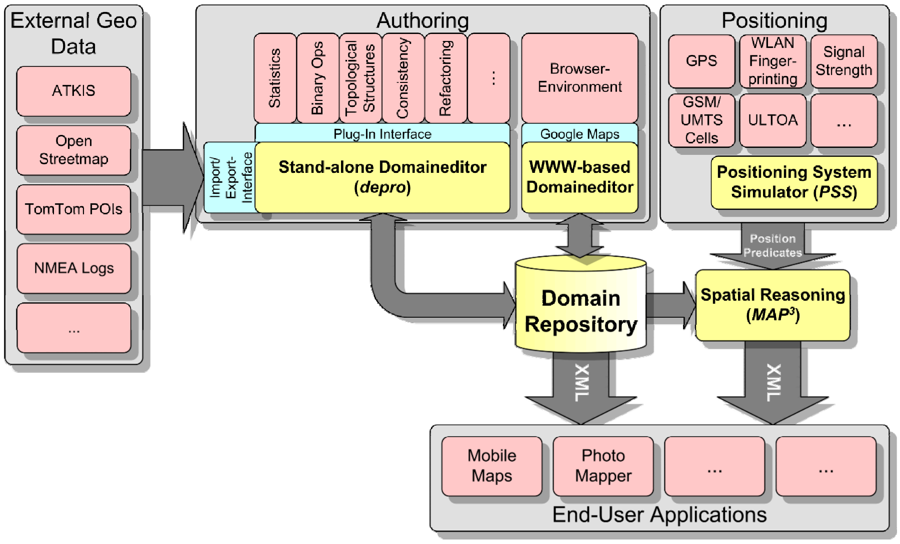

Fig. 1. The Hybris environment

- The geo data authoring tool is called *depro*. Besides display and modification functions it provides a powerful plug-in interface that allows the easy integration of new components. In addition to the stand-alone editor, a Web-based variation based on Google Maps is realized.
- The *Domain Repository* stores the corresponding geo data. We identified a number of requirements that the geo data model should meet (see below). In the current implementation, the domain repository simply consists of a directory tree of XML files, but also the storage in spatial databases is conceivable.
- A mechanism called MAP^3 allows to reason about the geo data in relation to the user's current position. As position sensors have certain sensor error distributions, reasoning about a position is a probabilistic mechanism. MAP^3 provides an efficient approach to represent and process position probability densities and in contrast to Kalman filters also support non-Gaussian densities.

We now provide some details.

1.1 The Authoring Environment

The traditional field that deals with geo data is land surveying. As nowadays land survey data is stored digitally, it can in principle be used for location-based services. However, the goals of land surveying often do not meet the requirements of location-based services, we thus introduce a new geo data model [3]. We identified a number of requirements that the geo model should meet, extended the traditional properties of geo data, which are *thematic*, *geometric* and *topological* properties and introduced *structural*, *organizational* and *meta data* properties.

Commercial systems in the area of location-based services often import geo data from hundreds of geo spatial databases. One of our goals was to represent all required geo information within a *single* data format. To get the required expressiveness, we first extended the list of traditional properties of geo objects (i.e. *geometric*, *thematic* and *topological* properties). The resulting list of properties (excluding the traditional ones) is:

- *Structural properties* are used to describe storage and access of geo data in technical infrastructures. E.g., inside the Nimbus project [1, 2] we used structural properties to perform a geometric lookup of geo objects that are stored in a distributed federation of servers. In contrast to topological properties, structural properties describe relations in terms, which are not directly perceived by end-users.
- *Organizational properties* are information about the generation process of geo data, e.g., unique identifiers to detect duplicate objects as a result of multiple imports. They answer questions such as: What is the data source, who modified an entry and how long is the entry expected to be valid? If the geometry is based on GPS measurements, how many satellites were available? Such data is important to achieve and preserve the quality of geo data. In contrast to structural properties, organizational properties describe non-technical characteristics.
- *Meta data* are names, images, sounds, or Web links. Even though structural and organizational properties are also meta data in a general meaning, this point only summarizes those properties that describe content perceivable by an end-user as meta data. Some meta data is intended only to be displayed to users, but others have to be included into a resolution process. E.g., the *time validity property* is used for geo objects that do not exist permanently such as fairs, weekly markets, or construction zones.

Inside the Hybris project, we use an XML language to represent geo objects, whereas each geo object is stored in an individual XML file. That simplifies the distribution of geo objects to different servers. Fig. 2 shows the main authoring tool to edit geo objects. The different properties are reflected by different views on the data.

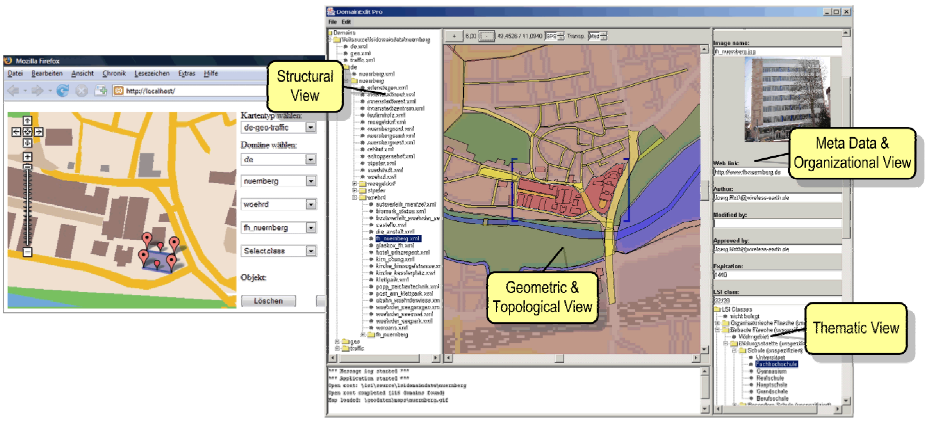

Fig. 2. The depro authoring environment (left: Web-based; right: stand-alone)

The editor provides a powerful plug-in interface to build future extensions. Currently plug-ins for refactoring, statistics, import/export, consistency checks, binary polygonal operations and for the creation of topological connections are implemented.

The plug-in interface significantly simplifies the creation of authoring functions as it already provides powerful functions such as geo coding of mouse positions and displaying maps often required for editing. In addition, the environment preserves consistency if plug-ins modify multiple domains simultaneously.

The major path to integrate huge amounts of geo data goes through the Import/Export interface. For important formats such as ATKIS (EDBS), GPS Logs (NMEA), Google Earth (KML), OpenStreetMaps (OSM) and TomTom POIs (OV2), import plug-ins are already implemented.

1.2 Reasoning Environment

MAP[3] (*Multi-Area Probability-based Positioning by Predicates*) [5] introduces a new approach for position sensor data fusion (fig. 3). Any piece of information about the location at any point in time is mapped to a *location predicate* that forms a kind of universal interface to any positioning system. Predicates are mapped either to probability density representations or operations on densities.

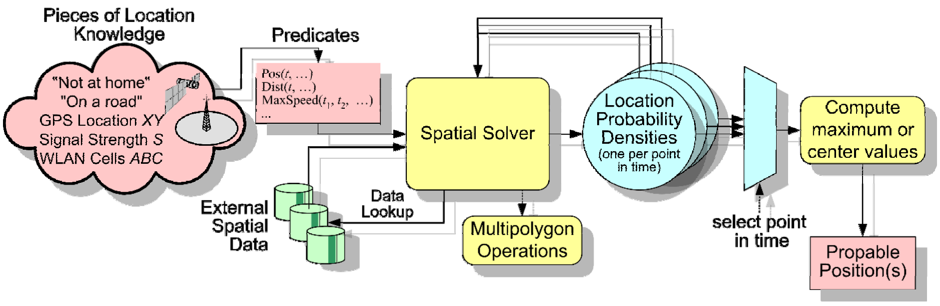

Fig. 3. The reasoning environment

Position probability densities f are mathematical constructions that need to be approximated for computation, if they do not follow some hard constrains such as Gaussian densities [4]. We use the following approximation f_{approx} for a position p

$$f(p) \approx f_{approx}(p) = \sum_{i=1}^{n} w_i \Lambda(p, mph_i)$$

where Λ is a characteristic function of a multipolygon with holes (mph_i) and w_i the weight of the respective mph. An mph represents the most common approximating two-dimensional structure that is widely available and efficiently implemented in many tool environments, software libraries and spatial databases.

The *Spatial Solver* component executes density operations (e.g. multiplication, convolution) with the help of these mph operations. Depending on the application, the most probable location or a set of local maximum values is computed. For details of the probabilistic reasoning mechanism see [5].

Fig. 3. Hybris applications (left: Buddy Finder, right: Photo Mapper)

3 Conclusions

Managing geo data and locations currently still is a cost intensive task. With the Hybris environment, an application developer mainly can concentrate on the application-dependent part. We verified the approach with the help of two location-based applications developed as student project: a buddy finder for mobile phones and an application that assigns locations to digital pictures (fig. 3). A developer and can rely on a powerful tool environment to manage geo data, especially on the convenient authoring environment that provides a plug-in interface to integrate new import and processing mechanisms. The innovative spatial reasoning approach MAP^3 allows the easy integration of different positioning systems and provides an effective position fusion mechanism.

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