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Geographic Learning Objects in Smart Cities Context

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Abstract. Nowadays, many cities around the world are trying to find smarter ways to manage challenges such as ensuring livable conditions in a context of rapid urban population growth. These cities are often referred to as S*mart Cities*. In the last years, researchers from many disciplines have contributed to the Smart Cities definition and implementation. In this paper we investigate how topics from two particular fields, such as Geographic Information and E-learning Systems, can be mixed in order to contribute to the Smart Cities cause. In particular, we introduce the Geographic Learning Object and discuss how such Geographic Learning Objects can be used in a Geographic Information System in order to provide information and learning content to the citizens of a Smart City.

Keywords: Smart Cities, E-Learning, Geographic Information System.

1 Introduction

Nowadays, urban areas are occupied by more than half the World's population [1-3]. This huge number of people inevitably generates new kinds of problems [4] and makes the cities difficult to manage. Many cities around the world, often referred to as S*mart Cities* [5], are trying to find smarter ways to manage challenges, such as ensuring livable conditions in a context of rapid urban population growth. Especially in this context, the complexity of such territory needs to be managed by appropriate tools. We think of a city, or better, of the territory where a city grows, as a place where citizens need to learn, and in particular, need to know where and how to learn, in order to actively contribute to the new scenarios that a Smart City is able to offer.

In the last years, researchers from many disciplines have contributed to the Smart Cities definition and implementation. In this paper we investigate how topics from two particular fields, such as Geographic Information Systems (GIS) and E-learning Systems, can be mixed in order to contribute to the Smart Cities cause, by exploiting the GIS capability of managing and analyzing a territory, together with the E-learning Systems capability of managing learning content. In particular, we investigated our hypothesis that in most e-learning content, expressed as Learning Objects (LO), there is some hidden geographic information, that can be revealed and used to improve the learning content and its search and traceability.

In fact, in geoscience studies [6-8] it is estimated that from 80% to 95% of all information and decisions in the public sector contain some geographic reference.

Thus, we argue that GIS are able to ensure a good contribution to Smart Cities, which are doubtless a public and territorial context.
As for the E-Learning component, in [9] Downes states that today the learning concept is closely related to the concept of Learning Objects, which are coherent content, that have been refined and standardized into a rigorous form, together with specifications on how to sequence and organize them into courses. In this sense, we think the city as the object of study, strewn with a large amount of LOs available for the citizens of a Smart City.
Starting from this definition, we analyzed several LO Standards and LO Repositories, in order to have an overview of the state of art in terms of *de jure* and *de facto* standards, and to verify whether and how the geographic context is taken into account within such repositories and metadata.
In this paper we introduce and define a new entity, the Geographic Learning Object (GLO), and discuss how such GLOs can be used in a GIS context in order to provide learning content to the citizens of a Smart City. As defined, a set of GLOs concerning the area of a Smart City can be used as an information layer in different types of Geographic Information Systems, which thus become the access point to a learning platform for the city.
The reminder of the paper is organized as follows. Section 2 introduces the context of the paper and analyzes systems related to our proposal. In Section 3 we summarize the state of art of *de jure* and *de facto* e-learning standards and we present a review of different Learning Object Repositories and Learning Object Metadata standard. Section 4 presents GLO definition in terms of structure and meaning. Section 5 discusses how GLOs can be used in a GIS context in order to provide learning content to the citizens of a Smart City. Section 6 presents the GLO system architecture and an initial system prototype. Section 7 draws the final conclusions.

2 Background and Related Work

This section introduces the context of the paper and analyzes systems related to our proposal, which joins several topics related to two particular fields, such as GIS and E-learning Systems, and specifically from different sub-areas of GIS and E-learning Systems such as geotagging and mobile learning. In particular, in this paper we investigate our hypothesis that in most e-learning content, expressed as Learning Objects, there is hidden geographic information, that can be revealed and used to improve the learning content and its research and traceability. To strengthen our hypothesis, geoscience studies estimate that in the last 20 years about 80% of all information contains some geographic reference [6]. In particular, in [7] it is specified that about 80% of all decisions in the public sector are based on georeferenced data. Furthermore, Perkins [8] updates the percentage claiming that today 95% is more accurate because of new technology such as cell phones, GPS devices and electronic toll collectors.
As reported in [10], nowadays, this huge variety of mobile devices providing integrated GPS receivers is the reason of the renaissance of location-based mobile applications and at the same time the reason of the widespread use of geolocating applications such as geotagging. This technique, mostly used for images, associates a

digital resource with a pair of geographical coordinates. The additional geographic information offers new teaching and learning possibilities, in particular in fields strongly dependent on geolocated data, such as civil engineering, geosciences or archeology. Moreover, as mentioned in [9], the combination of geotagging with other Web 2.0 technologies provides a further contribution to e-Learning 2.0. Our proposal builds upon the geotagging technique, but to our knowledge this is the first paper which addresses the problem of associating more than just a pair of geographic coordinates to a digital learning resource.

An intuition similar to our idea stimulated other studies [11-13], where micro-blogging services like Twitter are analyzed in order to extract hidden geographic patterns. In this case, differently from our approach, the focus is both to discover language patterns and to extract users' interests starting from the analysis of geo-tagged messages. Our proposal, in fact, is not to present a data mining algorithm which uses existing geographic coordinates, but to provide a flexible structure which allows the user to easily associate a geographic context to a learning content.

As for the E-learning, we started from the concept of LO, which as Downes claims [9], today are closely related to the learning concept. They are coherent content, that have been refined and standardized into a rigorous form together with specifications on how to sequence and organize them into courses. It is worth to notice that in the recent past much work has been done about LOs, thus implying that nowadays this line of research seems to raise little interest, but also implying that a huge amount of LOs has been created over the time. One of the goals of our proposal is the reuse and the improvement of the existing LOs content through the integration of geographical contexts.

As combination of GIS and E-learning, the Mobile learning (m-Learning) area is another area related to our topic. It is focused on e-Learning using mobile devices and, as reported in [14], it deals with applications that support learning anywhere, anytime. For instance, the Handheld-Centric Classroom approach, presented in [15], uses mobile devices as an integral part of a learning activity. As reported in [16], a main characteristic of mobile learning is the possibility of ongoing assessment and feedback. An interesting example of using m-Learning in higher education is the EU research project RAFT (Remote Accessible Field Trips), which was conducted from 2002 to 2005 [17]. The goal of RAFT project was the support of classes with virtual excursions, using portable Internet-conferencing tools. A common feature between these applications and our approach is related to study topics which rely on education *in-the-field*, for which m-Learning is particularly interesting. An important difference with respect to our approach is that the learning content we propose could be accessed through m-Learning applications, but their use is not limited to the mobile environment.

3 Learning Object Repositories and Metadata

We analyzed different Learning Object Repositories and Learning Object Metadata standards in order to have an overview of the state of art in terms of *de jure* and *de facto* e-learning standards, and to verify whether and how the geographic context is taken into account within such repositories and metadata.

A Learning Object Repository (LOR) is one kind of digital library which allows users or educators to use, manage and share educational resources. LORs store educational resources as well as their metadata, which are standardized properties of the learning objects that make their retrieval possible throughout the world, using various kinds of query software. The GLOBE (Global Learning Objects Brokering Exchange) alliance is an interesting project which federates several LORs and whose purpose is to manage LORs that aggregate high quality learning content. Inside it about 1.2 million learning objects can be shared. GLOBE uses IEEE LOM as a common medium to enable the sharing of learning materials. IEEE LOM standard has been published in 2002, and proposes around 50 different elements grouped into nine categories: General, Lifecycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation and Classification. Each GLOBE member adheres to the GLOBE Application Profile, a document describing the fields that should be present in the metadata in order to share resources with GLOBE. In [18] is reported an interesting large-scale study about the use and quality of more than 50% (630.317) of LOM instances in GLOBE. Table 1 shows the list of repositories analyzed in this large-scale study, and in Figure 1 the percentage of usage of different LOM data elements in GLOBE is shown.

Table 1. Learning Object Repositories analyzed in GLOBE [18].

Repository	Instances
ARIADNE Foundation	374857
Learning Resource Exchange (LRE)	169736
Community on Learning Objects (LACLO)	49943
OER Commons (OER)	25794
Korean OCW (KOCW)	7183
LO Repository Network (LORNET)	1804
Open University Japan (OUJ)	1000

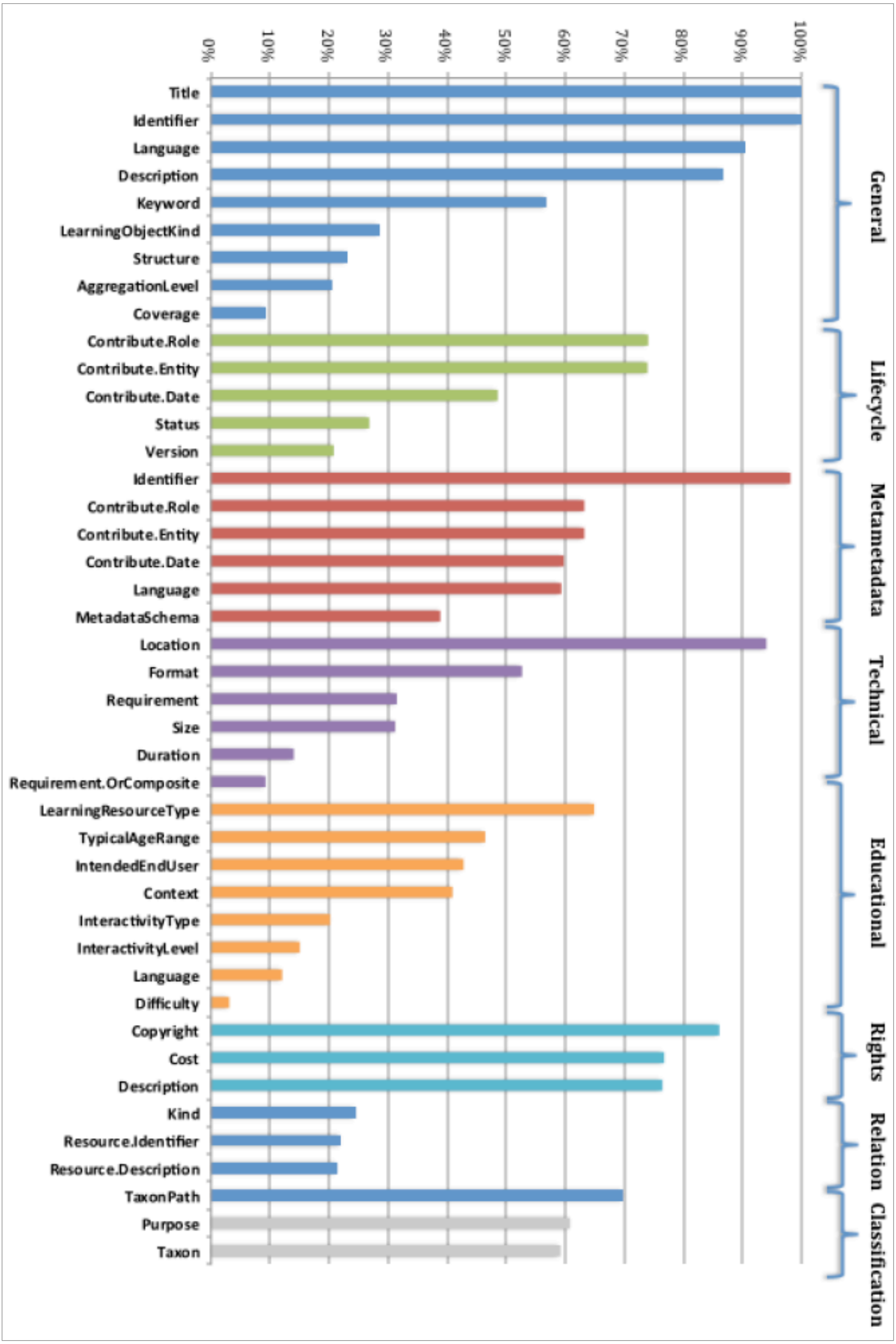

Fig. 1. Percentage of Usage of Different LOM Data Elements in GLOBE [18].

Among the many conclusions of [18], two of them are interesting for our work. The former is that only 20 of the 50 data elements are used more than 60% of the time, thus suggesting a core of elements that we can use. However, data on Figure 1 shows that only 2 elements are used 100% of the times, and 7 elements are used more than 80% of the times, thus suggesting that LOM is not much used by Globe providers. The latter conclusion is that 3 main extended data elements have been found which were used by GLOBE providers, but are not present in LOM standard:

- *general:learningobjectkind,*
- *technical:geolocation,*
- *general:subtitle.*

The need to enrich LOM standard with the first two elements in the list above, both from MACE (Metadata for Architectural Contents in Europe) Application Profile, clearly suggests that in LOM standard there are insufficient elements to associate a significant and usable geographic context to the learning objects. In fact, there are two elements used for this purpose in the LOM standard, *coverage* and *location*. The former is a general purpose element describing the extent or the scope of the content of the learning object as *LangString* data type, and it typically includes spatial location, temporal period or jurisdiction. Moreover the *coverage* element, according to [18], is used in less than 10% of the studied cases. The latter is a string that is used to access this learning object. According to IEEE LOM explanation, it may be a location (e.g., Universal Resource Locator), or a method that resolves to a location (e.g., Universal Resource Identifier), but a note suggests that "this is where the learning object described by this metadata instance is physically located".
More attention to this aspect has been given in the MACE (Metadata for Architectural Contents in Europe) [19], a project which connects several repositories of architectural knowledge and enriches their contents with new metadata which can be used to support different learning scenarios. In fact, the attribute *general:learningobjectkind* is added to LOM in order to distinguish between a real world object (i.e. a building) or a media object (digital) that describes that real world object. Moreover, the attribute *technical:geolocation* is added, in order to add geocoordinates in the case of a real world object such as a building. This attribute enables the creation of mobile applications where users walk through a city and get extra information about the buildings in their neighborhood.
Although in the MACE project the possibility of associating a geographic context to a learning object is provided, we argue that associating only one or more geolocation (a pair of coordinates) to a learning object can severely limit the use of that resource. As reported in the previous section, the geotagging technique presents a stronger limitation, that is, just a pair of geographic coordinates can be associated to a digital resource. In the next section we present our proposal, the Geographic Learning Object, whose aim is to fill this gap.

4 Geographic Learning Objects

In this section we define the new entity which is the focus of our proposal, the Geographic Learning Object (GLO). A GLO is defined as an extension of a Learning Object which embeds information about more geographic contexts where the Learning Object is valid and/or applicable. As shown in Figure 2, we define the geographic contexts as a sequence of n pairs <Geometry, Meaning>, where Geometry is a generic geographic information which can take a variety of shapes, in agreement with the geometry class of the Open Geospatial Consortium (OGC) Standard for Geographic information - Simple Feature[1], and Meaning is the meaning associated with each Geometry instance. It is worth nothing that such a structure does not modify the structure of the LO which it extends, thus allowing to adapt it to any type of existing LO for the purpose of reuse and improvement of its content.

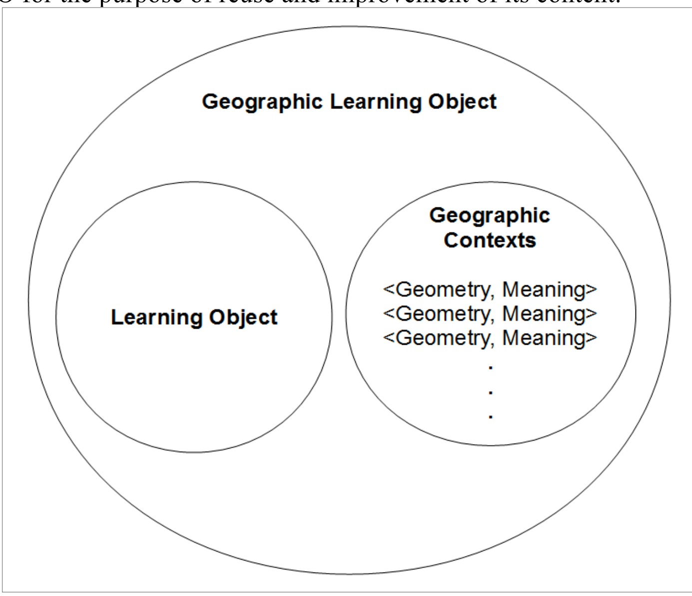

Fig. 2. Geographic Learning Object Structure.

Figure 3 shows the hierarchy of the geometry class in the OGC Standard, which can be instantiated with several kind of shapes, such as

- Points,
- LineStrings,
- Polygons,
- MultiPoint,
- MultiLineString,
- MultiPolygon,
- Curves,
- Surfaces,
- MultiCurve and
- MultiSurface.

1 http://www.opengeospatial.org/standards/sfa

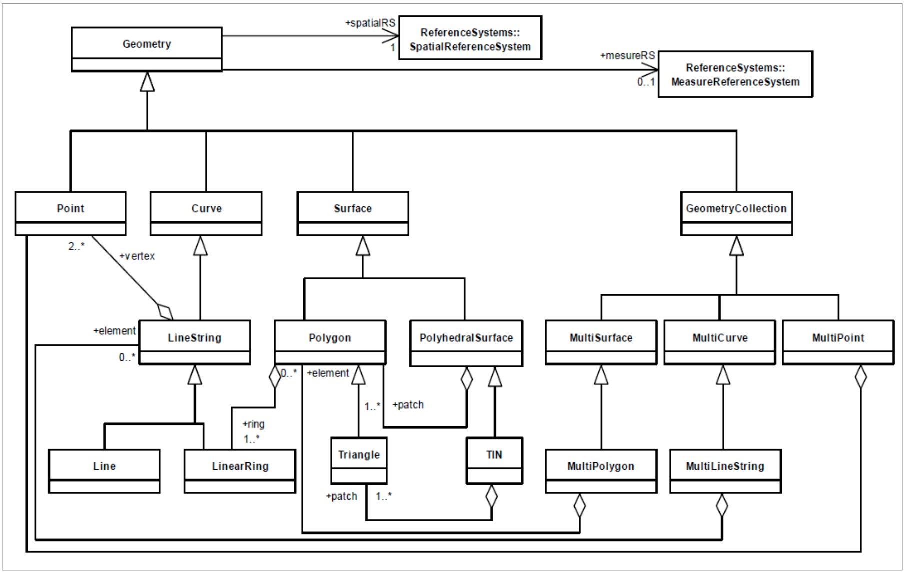

Fig. 3. OGC Geometry class hierarchy.

By using GLO structure shown in Figure 2, a Learning Object can be associated with n different shapes, each with a different meaning. Such a solution allows to overcome the limit of associating a single pair of coordinates to a GLO, and it allows to explicit the geographic information that is often hidden inside a learning content.

As an example, a Marine Biology study could be associated with a Multipolygon (collection of polygons) corresponding to the areas where the studied species live, but it could be also associated with a point, corresponding to the research center where the study was carried out, or it could be also associated with a Multipoint (collection of points) representing the locations where the measurements were performed.

Another example is a biography of a historical figure, which could be associated with many points, representing the birthplace, different places where he lived, and the place of death.

5 Geographic Learning Objects and Smart Cities

In this section we discuss how GLOs can be used in a GIS context in order to provide learning content to citizens of a Smart City. In particular, GLOs can be used to access learning objects about the city in an alternative way, namely by using the territory where a city grows both as the starting point and as the filter of a content learning research. As mentioned above, we analyzed different Learning Object Repositories to verify whether and how the geographic context is taken into account within such repositories. In particular, we reviewed several learning objects from ARIADNE and

Learning Resource Exchange Repositories, which contain most of the elements analyzed in GLOBE project (see Table 1).
We report here some learning objects we reviewed, all of them contained in the Learning Resource Exchange Repository, showing how different geographic contexts could be associated to them by using our proposal, and how the GLOs obtained could be useful in a Smart City context.

Learning object #1

LO #1 is associated to the metadata shown in Table 2.

Table 2. Learning Object #1, “School at home". "Look what we do!".

Title:	“School at home". "Look what we do!" Woodland and forest fires (Verge del Tallat Primary School in Blancafort)
Description:	With the help of forestry agents in the Conca de Barbera area, pupils at Verge del Tallat Primary School in Blancafort get to know the characteristics of the Mediterranean woodland, with special emphasis on the disastrous ecological effects of forest fires.
User's Tags:	Not Available
Descriptors:	environmental education environmental protection forest
Keywords:	Not Available
Age range:	18-99
Resource type:	website
Available in:	ca
License:	See License
Provider:	XTEC, Spain
Read about in:	ca de en es fr it pt

As the reader can see, no geographic feature is used in the set of metadata associated to the LO, although there are many geographic references in the title and in the description. By using the structure we propose, such geographic information could be explicited and stored as different geometries. For instance, a polygon representing the *Blancafort* municipality, a point representing the address of the *Verge del Tallat* Primary School, a Polygon representing the *Conca de Barbera* area.
Moreover, on the website a video is available, where an excursion made by the children of the *Verge del Tallat* Primary School in the *Conca de Barbera* area is shown. Then, other geometries could be added, such as a Linestring representing the route taken, or a MultiPoint representing the points where the children have planted trees.

Learning object #2

LO #2 is associated to the metadata shown in Table 3.

Table 3. Learning Object #2, First Sign of Civics.

Title:	First Sign of Civics
Description:	Photographic Print 9.5 x 12 cm, belonging to the World Heritage photographic collection of the INDIRE. The photo was taken at the Elementary School Fabio Filzi in Trieste: Pupils are concentrated on observing an educational program entitled “politeness in family”. These are the first lessons in civics.
User's Tags:	Not Available
Descriptors:	child girl primary education primary school citizenship civics behavior interpersonal relations social life family
Keywords:	Not Available
Age range:	Not Available
Resource type:	image
Available in:	it
License:	Not Available
Provider:	ANSAS, Italy
Read about in:	it

Also in this case, no geographic feature is used in the set of metadata associated to the LO, although there are some geographic references in the title and in the description. By using GLO structure, such geographic information could be made explicit and stored as different geometries. For instance, a Point representing the address of the Elementary School Fabio Filzi in the city of Trieste, or a Point representing the address of the INDIRE (Istituto Nazionale di Documentazione, Innovazione e Ricerca Educativa), are immediately derivable. In particular, since the image belongs to the World Heritage photographic collection of the INDIRE, it is possible that, without the explicit geographic reference we propose, pupils and teachers of this Elementary School may not know that the rudiments of civics have been studied in their school.

Learning object #3

LO #3 is associated to the metadata shown in Table 4.

Table 4. Learning Object #2, Qui és W.A. Mozart?

Title:	Qui és W.A. Mozart? Who is W.A. Mozart?
Description:	Recurs didàctic interactiu que presenta la vida, els viatges i l'època de Mozart a Catalunya. Conté una animació que explica l'argument de "La Flauta Màgica" i jocs interactius com el de la roba, els instruments, els edificis i el dels cantants. Tot plegat per conèixer d'una manera lúdica la figura i l'època de W.A.Mozart. Interactive educational resource that presents life, travel and the time of Mozart in Catalonia. It contains an animation that explains the plot of "The Magic Flute" and interactive games such as clothes, tools, buildings and singers. All this in a playful way to know the life and times of Mozart.
User's Tags:	klassieke muziek mozart
Descriptors:	history of arts music music education music listening
Keywords:	Not Available

Age range:	6 -16
Resource type:	drill and practice , website
Available in:	ca
License:	CC by NC -SA
Provider:	XTEC, Spain
Read about in:	ca

As the previous LOs, no geographic feature is used in the set of metadata associated to this LO, but in this case no geographic references are mentioned in the title and in the description. However, in two sections of the website the travels of Mozart in Europe and, in particular, in Catalonia are described. Once again, by using the structure we propose, such geographic information could be made explicit and stored as different geometries. For instance, several Linestrings representing its travels, and several Points representing places in the cities visited during its long concert tours, such as *Munich, Vienna, Prague, Mannheim, Paris, London, The Hague, Zurich, Donaueschingen, Salzburg, Bologna, Rome, Milan, Augsburg, Leipzig, Dresden, Berlin, Frankfurt,* and so on.

From the analysis of these LOs, it can be deduced that the more information is contained in the LOs, the more geographic information can be extracted and revealed, as in LOs #1 and #3. Also when the LO contains very few information, as in LO #2, there might still be some hidden geographic information that can be useful in specific contexts.

As defined, a set of GLOs concerning the area of a Smart City, such as the samples above mentioned, can be used as information layer in different types of Geographic Information Systems, which thus become the access point to a learning platform of the city. For instance, a user can access the learning content by using a webgis and/or a mobile device. In the former, GLOs could be represented as points or areas on a map, depending on the zoom level set by the user. In the latter, the position of the user could be used to filter GLOs near the user and GLOs could be represented at a level of granularity that depends on the current distance of the user from the GLO.

6 GLO System Architecture and Prototype

A first prototype system, based on the client-server architecture shown in Figure 5, is being implemented. The core component of the architecture is represented by a Geographic Database containing GLOs, which are provided in a standard format by a standard service in order to be used in different types of client applications (e.g., maps on PCs, tablets, smart-phones, or augmented reality on mobile devices). GLOs in the Geo DB are both linked to already existing LOs (external LORs) or new LOs (internal LOR).

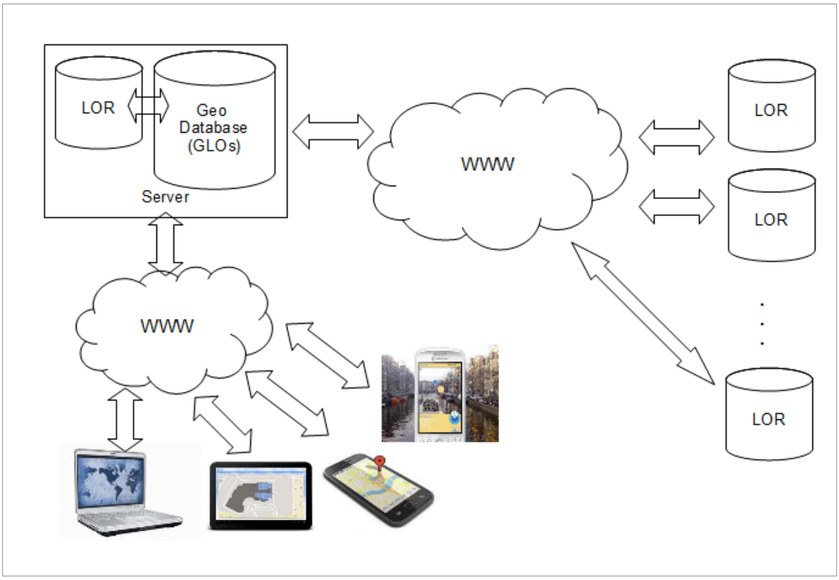

Fig. 5. GLO system architecture.

In particular, the server side in being implemented by using PostgreSQL DBMS[2], with PostGIS[3] component as geospatial extension in order to store GLOs, OSGeo Mapserver[4], an Open Source geographic data rendering engine, in order to publish data through the standard (WFS[5]) web service in the Geography Markup Language (GML[6]) format.
The client side of the system is being implemented as an application able to show GLOs in two different display modes, map and augmented reality, by extending the Mixare[7] (mix Augmented Reality Engine) Application, a free open source augmented reality browser, published under the GPLv3.

7 Conclusion

In this paper we proposed a new entity, the Geographic Learning Object, defined as an extension of a Learning Object which embeds information about a geographic context, where the Learning Object is valid and/or applicable. Our proposal mixes topics from two particular fields, such as Geographic Information Systems and E-learning Systems, by exploiting the GIS capability of managing and analyzing a

2 http://www.postgresql.org/
3 http://postgis.net/
4 http://mapserver.org/
5 http://www.opengeospatial.org/standards/wfs
6 http://www.opengeospatial.org/standards/gml
7 http://www.mixare.org/

territory, and the E-learning Systems capability of managing learning content. In particular, we investigated our hypothesis that in most e-learning content, expressed as learning objects, there is hidden geographic information that can be revealed and used to improve the learning content, and its search and traceability, in order to contribute to the Smart Cities cause. In fact, as defined, a set of GLOs concerning the area of a Smart City can be used as information layer in different types of Geographic Information Systems, which thus become the access point of a learning platform of the city.

As future work, we aim to compete the implementation of the prototype which allows users to easily associate a geographic context to a learning object, as defined in the GLO structure. Moreover, we plan to improve GLO structure by adding information also about the temporal context.

Finally, we aim to test the effectiveness and usability of the system by designing a usability study with potential users in the educational domain.

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