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## **Enhancing IMS QTI assessment with web maps**

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**Abstract:** Although the importance of maps in Geography education, current eLearning systems do not take benefit from the possibilities that web maps offer. In this paper we describe an IMS QTI assessment engine enhanced with web maps from Google Maps. The system enables the user to interact with the map to answer questions, providing a more natural interface for geographic information. The concept of map interaction has been introduced to represent the different ways of processing the student actions on the map. Depending on the selected map interaction, different spatial operations are applied to validate the correctness of responses.

**Keywords:** eLearning, assessment, IMS QTI, Geographic Information, Google Maps, Web Map Service

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### **1 Introduction**

Humans have used maps to represent parts of the Earth since the Stone Age. During these millennia, the science of Cartography has evolved from portraying simple representations on walls to the extremely precise real-time-populated interactive web maps we can find today. Maps are the most widely used tool in Geography to represent those features and phenomena that have a spatial component. Maps are also used in other disciplines where space may be an influential factor such as History, Economics and Business, Sociology, Politics, Biology or Environmental Science, among others.

From a pedagogical perspective, maps also play a key role in Geography education. In fact, understanding maps is a key competence that children have to acquire. Maps are widely used in Geography learning activities and contents. Maps are needed by K-12 education students to understand their local and global environment, and how human activities take place in these environments. Higher education and long-life learning also make a frequent use of maps.

However, the use of maps in eLearning has been very reduced, mainly constrained to non-interactive still images. Web map servers offer the possibility of incorporating more elaborated maps in the learning process, with more interactivity and learning possibilities.

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The importance of maps in Geography education can be extended to assessment activities, since maps are usually needed to evaluate the acquisition of competences in Geography and related fields. In this work we focus on how maps can be used in the process of assessment in an eLearning platform. We are interested in an assessment system supporting the visualization of web maps and providing the typical interaction tools such as zoom in or zoom out. Furthermore, the system has to enable students to answer questions by interacting with the map in different ways:

- clicking on key elements on the map
- sketching points, lines or polygons on the map to represent geographic elements, such as cities, rivers or countries respectively.

Section 2 describes the main specification for interoperable assessment, IMS QTI. It also describes APIS, the engine that we have upgraded and used in our experiments with mapping services for assessment. Section 3 focuses on the main approaches for serving maps on the web: the OGC Web Map Service specification and Google Maps. Section 4 presents our approach of combining the APIS engine and Google Maps through a middleware that we have developed. Finally, Section 5 summarizes the main conclusions and states some lines for future work.

## **2. IMS QTI and the APIS engine**

Question and Test Interoperability (QTI) [1] is the IMS specification for assessment. It provides a data model for the representation of questions (items) and tests and their corresponding outcomes. It enables the exchange of questions and tests between authoring tools, item banks, test composition tools, learning systems or assessment delivery systems, to name a few. Although the model is defined in abstract terms, an XML implementation is also provided in the specification.

The main elements of the QTI data model are:

- Item: it is the smallest interchangeable QTI element that stores the question presented to the user along with the associated metadata such as the reproduction instructions, user answers processing mode, hints, and feedback.
- Section: it represents a composite part of the assessment test or exam.
- Test: it is an entire QTI instance that embodies a single assessment test. Its structure is divided into sections and subsections and contains sequential information along with the method(s) to use for combining individual questions scores/marks to form the overall test grade.

The last two versions of the specification are 2.0 and 2.1. QTI 2.0 focuses on the representation of individual questions, introducing a long list of interactions. An interaction describes how the user “interacts” with an individual question, and can be seen as a type of question. An example of interaction, probably the most usual, is the simple choice question, where the user can select just one from several possible responses to the question, and where just one of them is correct. On the other hand, QTI 2.1 (still in public draft phase) deals with tests and their internal organization in sections. QTI 2.1 also defines complex ways of producing results reports for a whole test.

An engine is necessary to run QTI tests. A QTI engine is the software component responsible to manage the QTI data model, processing the XML file and generating the

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outcomes according to the user actions. There are two main open source implementations of QTI engines that we describe now.

The APIS (Assessment Provision through Interoperable Segments) QTI 2.0 engine [2] was originally created by Strathclyde University. A modular item-rendering engine was defined, although only some of the most widely used interactions were implemented. This engine addresses the operations required by potential tools defined in the Open Knowledge Initiative (OKI) [3] and IMS Web Services [4].

The R2Q2 (Rendering and Response processing services for QTIv2 questions) project [5,6] has been developed more recently by the University of Southampton. It is a new implementation built from scratch, aiming at providing a complete renderer and response processing engine, properly structured. Due to its function-modular design (Renderer, Processor,...) and use of internal Web Services, the system facilitates future enhancement and can be changed to suit any application.

However, both implementations are limited to the QTI 2.0 specification, and consequently can only process individual questions. We have largely upgraded the APIS engine to making it compliant with QTI 2.1, introducing new functionalities mainly referring to: test context instead of just questions, a wide range of new elements related to the test level, new and more complex response processing and new types of interactions. This new version of APIS is available at Source Forge at <http://sourceforge.net/projects/newapis>. A more detailed description of the structure of the new APIS engine can be found in [7].

This upgraded APIS engine will be the base for processing those questions needing mapping services, as it will be described in Section 4.

### **3. Google Maps and other mapping services**

Serving maps on the Internet has become very popular in the last few years. A multitude of implementations of mapping servers exists, both commercial and open source, using different programming languages. In this context of heterogeneous tools, the Open Geospatial Consortium (OGC) is the international organization, integrated by companies, governmental agencies and universities, that is leading the definition of consensus standards in the field of geospatial services. Several OGC specifications have become ISO standards. In the domain of map servers, OGC has developed the Web Map Service specification (WMS) [8], which defines a service-based interface for a standard map server consisting of the following three main services:

- *GetCapabilities*, which returns metadata related to the server
- *GetMap*, which returns a map (an image) given some parameters as the coordinates of the centre of the map, zoom level, ...
- *GetFeatureInfo*, which returns the information of a given feature(s) appearing on the map, given a pair of pixel coordinates

Any WMS-compliant server may define other services, but have to implement these three basic ones, that in fact are sufficient to develop an interactive on-line map. There are several commercial and open source implementations of WMS. MapServer [9], developed by the University of Minnesota, is the most widely used open source implementation of WMS. WMS has been adopted by ISO as the ISO 19128 Geographic information - Web Map server interface [10], becoming a normative international standard.

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However, the appearance of Google Earth and Google Maps has change the world of map servers. Google Maps is a simple web-based map viewer, while Google Earth is a richer desktop application that provides an attractive 3D visualization, as well as other extra features. Both tools offer a free world-wide cartography including street-level information for most Western countries, as well as satellite image at different resolutions. Google has also defined KML, a simple XML-based file format for storing vector-based (points, lines and polygons) geographic information. Users around the world have produced KML files to show their favourite spots, routes, etc, that can be seen on the free cartography that Google offers.

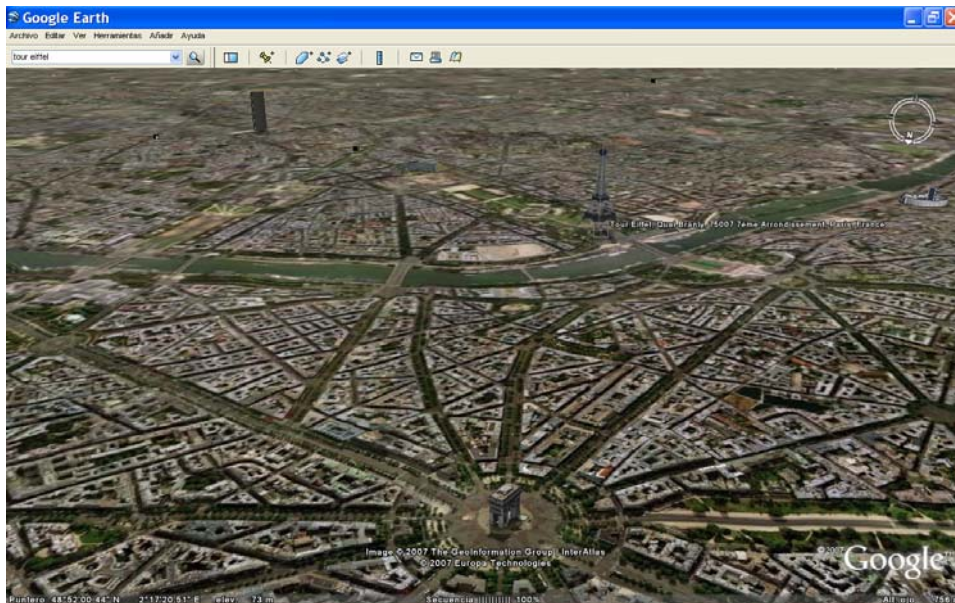


Figure 1. 3D view of Paris in Google Earth, including several 3D models of famous buildings

Although Google Earth and Google Maps are not compliant to OGC standards, their free cartography, simple but rich interface and the possibility for users to add their own geographic data, have massively popularized these tools.

Furthermore, Google Maps provides a simple JavaScript API that enables third parties to publish the location of spots on the map, and to connect to other web services through AJAX calls. An example can be seen in the Figure 2, where Google Maps is used to show the position of San Francisco buses in real time.

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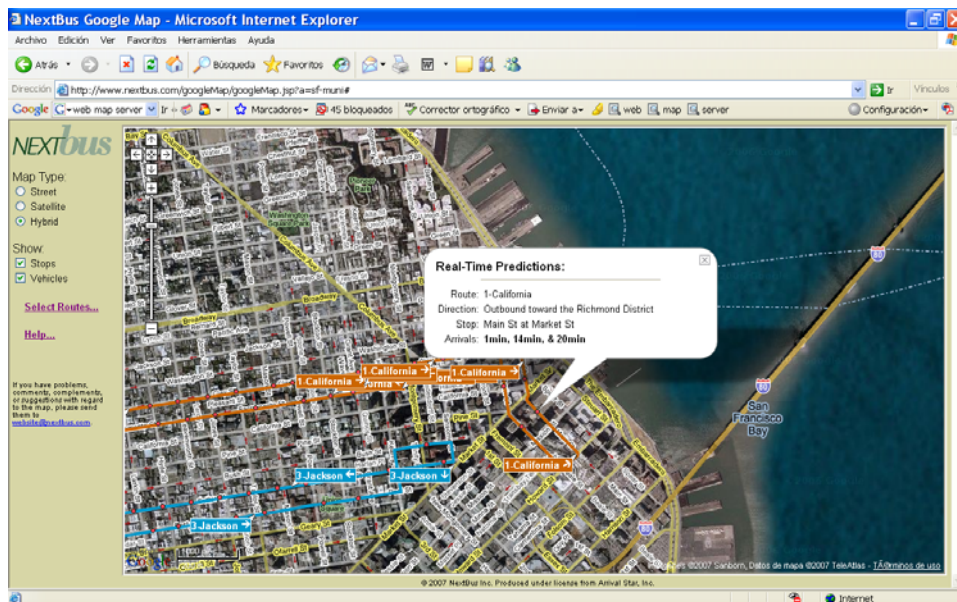


Figure 2. San Francisco buses in real time, at <http://www.nextbus.com/>

Due to its popularity and easy API, we have decided to build the first prototype of our map-enabled QTI service on Google Maps. Nevertheless, as it will be discussed later, our plans include to extend the middleware to also support OGC-compliant map servers.

### 4. Connecting APIS and Google Maps


The connection between APIS and Google Maps is carried out through a middleware that we have developed. This middleware is the responsible for generating the Google Maps JavaScript functions to show the map. It also processes the actions of the user on the map and converts them into QTI responses that can be processed by APIS. The middleware encapsulates all the Google Maps code, and consequently the APIS engine does not need changes. Providing support for WMS would require modifications in the middleware, but not in APIS.

A map can be inserted into a question through the tag *map* in the *itemBody*, in the same way as an image is inserted. The *map* element has an attribute *src* that contains the URL of a file describing the map. This file contains the coordinates of the centre of the map (according to the WGS84 reference system) and the zoom level (1 is world-wide level and 18 is street-level). Other parameters can also be set concerning visualization aspects.

```
<Centre>  
  <Latitude>40.346544</Latitude>  
  <Length>-3.757324</Length>  
  <Zoom>5</Zoom>  
</Centre>
```

Once APIS detects a *map* tag, it calls the middleware that parses the XML file and generates the JavaScript code necessary to set the right map. This JavaScript code is inserted into the web page that presents the question. For some questions this is the whole process since only showing the map is required, with no interaction, exactly like an image. Figure 3 shows an example. Note that, unlike a still image, an interactive map enables the user to freely put the displayed area in context by using zoom controls or by moving the map to explore neighbouring areas. Nevertheless, the teacher can lock this possibilities when necessary, through some parameters in the XML file.

Look at the map and answer the question below;



Which is the peninsula that you can see on the map:

- Italian Peninsula
- Iberian Peninsula
- Balkan Peninsula
- Kola Peninsula

submit

Figure 3. Example of a simple choice question showing a map from Google Maps

However, we are mainly interested on more complex questions that have to be answered by the user by interacting with the map. As an example, we can see the question in Figure 4, where the user is required to click on the largest Catalan city.

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Look at the map and answer the question below,



Which is the largest city in Catalonia?

submit

Figure 4. Example of a simple choice question requiring the user to interact with the map

We can observe that, like in the example of the Iberian Peninsula above, this is a simple choice question, with four choices and just one valid. However the four options are not explicitly included in the text below the map, but are included as markers on the map. The user is required to click on the markers to answer the question, providing a more natural interaction.

The QTI file contains the information indicating that the right answer is Barcelona, in the *responseDeclaration* element. However, the four choices are not explicitly declared in the *choiceInteraction* element, since they should not appear in the text below the map. Instead, choices are declared as *GMapInteraction*, which indicates to APIS that the interaction for this question is defined in the map description file and consequently, passing the responsibility to the middleware. The middleware has to generate the JavaScript functions that handle users clicks, and have to convert these clicks on a string with the selected choice (Barcelona, Girona, Tarragona or Lleida) that will be sent back to APIS. APIS will then check whether the selected choice is the right answer (Barcelona) or not, in the normal way. Note that the only change introduced to APIS is the detection of the *GMapInteraction* type of choice, while all the geographic logic is managed by the middleware through JavaScript functions.

This method enables the use of maps in other types of QTI interactions. For instance, the following image shows an *orderInteraction*, where the user is prompted to order the four Catalan capitals according to their population.

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Look at the map and answer the question below.



Barcelona  
Tarragona  
Lleida  
Girona

Order these Catalan cities according to their population

Figure 5. Example of an order interaction requiring the user to interact with the map

Furthermore, we can define more complex ways of interacting with the map. In the following example, the user is prompted to click on Italy, and there is an invisible polygon defining the area that is considered as the right answer.

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Figure 6. Example of a new type of question: *PointIntoPoligon* map interaction

Note that although this can be modelled as a simple choice question with two possibilities: *Italy* (right choice) or *outside Italy* (wrong choice), we have to define how this has to be handled in Google Maps. This is an example of what we have called *map interactions*, which are different than question interactions. A map interaction defines how a given answer and the solution are processed (through spatial operations) to validate the correctness of the answer, and it is defined in the XML file describing the map. In this case, the map interaction is a *PointIntoPolygon*, and has two parameters: the polygon defining Italy, and a Boolean value indicating that the polygon is kept hidden. Note that the middleware, and not APIS, is the responsible of evaluating the map interaction, i.e. checking whether the user has clicked inside the polygon that defines Italy or not.

We have defined a list of other types of map interactions, that basically correspond to the different topological relations. In the following example, where the user is prompted to draw the border line between Spain and Portugal, the map interaction is a *LineIntoBufferedLine*. In this case, the solution is a line that is widened (through a buffer spatial operator) to a certain distance, for instance 50 km. This distance is set in the XML file. The middleware has to check whether the line that the user has drawn is inside the buffered line or not.

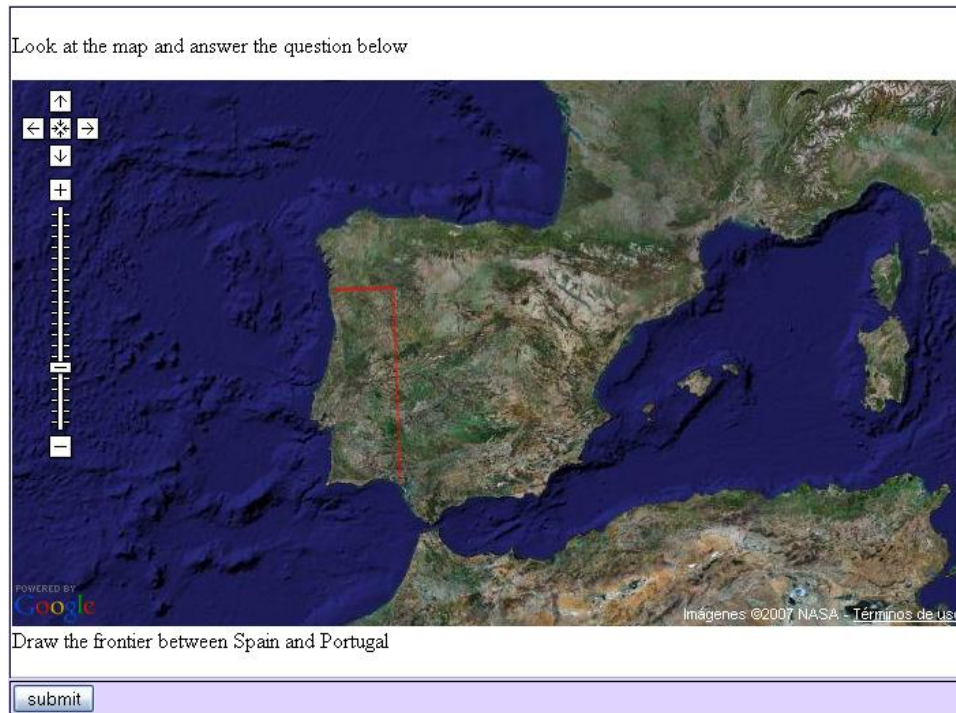


Figure 6. Example of *LineIntoBufferedLine* map interaction

## 5. Conclusions and future work

Maps are an important element in Geography education. An eLearning approach should not skip both the necessity and the potential of the use of maps in Geography learning. In particular, assessment can be improved if interactions with maps are supported, enabling users to click or sketch on maps.

We have presented a middleware-based approach to connect the APIS QTI engine and Google Maps. This approach enables the definition of mapping services for assessment that involve just some minor changes to the APIS QTI engine.

The use of interactive maps introduce the possibility of new ways of interaction with questions. The user can be prompted to click on markers instead of selecting text options, providing a more natural way of interacting with geographic information. Furthermore, the user can also be asked to draw sketches (points, lines or polygons) as his/her response to a question, introducing the concept of map interactions that define how the correctness of the answer is processed. This way, new types of queries not covered by QTI can be defined.

Our plans for future work related to this paper include three main lines. The first one consists in the development of a new middleware to support the connection to WMS servers, such as MapServer. A second line is related to a new editor for QTI 2.1 that we are currently developing. We plan to include a module enabling authors to graphically create map-enabled questions and map interactions. Finally, as a third line, we would like

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to explore the definition of new types of questions, with other map interactions including support for more geometries and spatial operations.

In addition, from our point of view, an eLearning environment should support the combination of different standards and specifications to provide richer contents and interactivity. We think that our work on enhancing assessment tests with maps has a more general aim, presenting an approach for integrating different specifications in an eLearning (assessment in this case) environment. In this line, we plan to integrate other services in our IMS QTI engine, following the middleware-based approach we have used here, to enable a collaborative and multimedia assessment. On the other hand, we also plan to extend our current middleware to be integrated in an IMS Learning Design (LD) [11] engine, again as a first exploratory example of combining different specifications with LD.

### **Acknowledgment**

This work has been partially sponsored by the TENCompetence Integrated Project that is funded by the European Commission's 6<sup>th</sup> Framework Programme, priority IST/Technology Enhanced Learning. Contract 027087 (<http://www.tencompetence.org>)

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