Towards a Virtual Hub for a wider Open Data community

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Abstract

The world of geographic information is extremely heterogeneous, especially in the field of Open data. System requirements are too various to be supported by a single unique system or technology limiting or impeding their interoperability. The proposed innovative approach facilitates the access to open data in a homogeneous way by means of broker connecting different data sources. An application integrating ancient cadasters and modern cartography is presented showing the flexibility of approach.

Keywords

Open data, brokering approach, interoperability, web services

1 Introduction

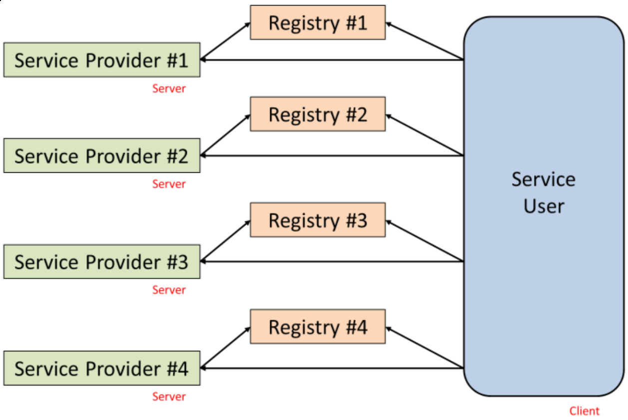
The world of geo-information (GI) is extremely heterogeneous. Different actors (Public Administrations, Research Centers, Citizens, etc.) with different roles (data creators, data providers, data users, etc.) are involved in the delivery and use of geo-information in different domains. This aspect is a significant barrier for the wide use of GI. Indeed, different users have different requirements in terms of communication protocols and technology, limiting a fruitful utilization of Open Data (OD).
In recent years, many important programs and initiatives have tried to address the ambitious objective of allowing a wider use of OD for production of services to the citizens in diverse communities and contexts. These programs recognize the needs of three main stakeholder types:

- Users;
- Data/Information Producers;
- Cyber(e)-Infrastructure Architects and Managers.

Examples of these initiatives are INSPIRE Directive established for geo-information of European Public Authorities, GMES/Copernicus core and downstream services for environmental and security applications from European Earth Observation data, the Global Earth Observation System of Systems (GEOSS) and the Eye on Earth and Shared Environmental Information System (SEIS) initiatives of the European Environmental Agency (EEA).
Generally, applications using OD are commonly achieved by implementing a stateless Client-Server (C-S) architectural style. In this style, server components offering a set of services, listen for requests upon those services, while client components desiring a service send a request to the specific server via its interface (Fielding, 2000). Almost invariably programs for OD sharing resemble the Service Oriented Architecture (SOA) archetype. In this architecture users play the role of service consumers; data producers represent service providers, while the cyber-infrastructure acts as a service clearinghouse or service registry, which is generally kept as simple as possible.
In a SOA approach, a cyber-infrastructure consists of a set of few selected common international standards (i.e. Web services protocols), common data models, and rules (e.g. best practices) adopted by both Data Producers and Users to publish available resources, discover

them and bind them. In other words, to enable interoperability C-S style, interfaces are objects of standardization at different levels, e.g. at the system, application, or infrastructure levels. The collection of these interface standards defines the interoperability arrangement (Ortiz, 2007; Schmidt, Hutchison, Lambros, and Phippen, 2005). Architectures implementing this pattern are known as Federated Architectures. In fact, they are based on the concept of "common/federal data model" and "common federal interoperability protocol(s)". Most Spatial Data Infrastructures (SDIs) around the world are based on this model. They use the SOA concept to mandate a limited set of standard specifications using a specific model to interconnect system components (i.e. clients and servers). Federated systems address interface heterogeneity by pushing common standards adoption.

a.



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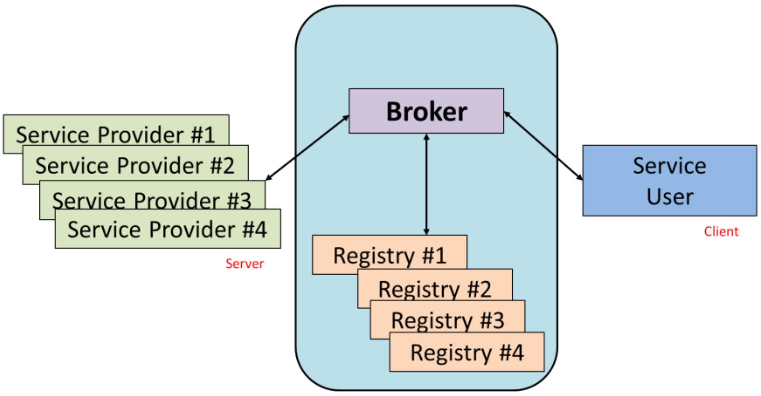

Figure 1: The difference between a Service-Oriented-Architectures-SOA approach(a) and a brokering approach (b).

The SOA approach works very well in consistent and controlled frameworks (e.g. enterprise environments), or where the approach is embedded in a strong legal framework that makes it mandatory for stakeholders to adopt the agreed standards and protocols (e.g. the NSDI for US federal government, and INSPIRE in Europe). However, each community generally tries to develop its own SDI using its own standard according to its specific requirements (Fig. 1). Indeed, it is noteworthy that the lack of agreed interoperability standards is not due to removable barriers, such as attitude, legal, financial or technological barriers. It is inherently impossible to define a common standard which is good for all the possible systems handling the geo-information. Even assuming that such a common standard suite would be developed, it would be too general for an effective utilization in real systems.
This is one of the reasons why, although several very good standards have been developed in the recent years (e.g. from OGC, ISO, etc.), they are not adopted by all the different domains. For this reason, the opportunity to access and integrate multiple sources for the development of new applications requires a work on different standards and protocols, which may be a quite complex and expensive task. The European project ENERGIC OD (European NEtwork for Redistributing Geospatial Information to user Communities - Open Data) tries to partially cope with the previously listed problems by developing a mediation system based on a brokering framework. Its aim is to lower the entry barriers, represented by the need to implement difficult and often unknown standards, to both providers and users for a wider use of OD.

In this paper the general concept of Virtual Hub adopted in ENERGIC OD is presented (Section 2) and an application of this approach integrating ancient cadasters and modern cartography will be presented (Section 3), showing the great flexibility of the brokering approach to access multiple and heterogeneous data.

2 ENERGIC OD: the brokering approach

As previously observed, the large variety of standards and protocols adopted by different data providers is an important barrier for an effective utilization of OD for production of services. A solution able to reduce the interoperability problems between data providers and applications requires extending the SOA archetype by introducing a new component that interconnects the different service protocols and standards, mediating their models and interface specifications. In addition, this component must work out all the necessary distribution and virtualization capabilities to lower the entry barriers for multidisciplinary applications. In ENERGIC OD, this intermediary role is played by an infrastructure called Virtual Hub, realizing a Brokering approach (Nativi, Craglia, and Pearlman, 2012).
The next subsections tries to define the primary requirements for an effective Virtual Hub implementation (Subsect. 2.1) and the main functionalities of the broker (Subsect. 2.2).

2.1 Interoperability issues

In recent years, several initiatives have been launched to improve the availability of geospatial information. These initiatives are developed not only by public agencies (e.g., INSPIRE, GMES/Copernicus, GEOSS) to provide a single point of access to global Earth observation resources and providing the framework for public authorities to publish themed data, but also informal "Volunteered GI" communities (e.g., OpenStreetMap with contributors; citizens and mapping parties), the professional geomatic community and open data networks (portals, "Hackathons" etc.). A valuable brokering framework should be aligned to this initiatives. This requires a connection with data sources that are already compliant with these initiatives in terms of standards and communication protocols. A trivial example is given by data formats: while in the word of professional geomatic community and PA a common data format for vector data are .dwg and .shp ESRI© files, in the word of mobile application development GeoJson and KML files are more popular. A brokering architecture should be able to discover both data sources to allow easy interoperability between different application fields and technologies. For the same reason, a format transformation module is needed. For example, accessibility to a data discovered as .shp should be given as KML or vice versa. When facing this problems the following issues should be addressed:

- Data harmonization, i.e. providing access to spatial data through network services that allow combining it with other harmonized data, using a common set of data product specifications;
- Interoperability of available public data, i.e. the possibility for spatial data sets to be combined and services to interact without repetitive manual intervention, so that the result is coherent and the added value of the data sets and services is enhanced ;
- Spatial inconsistency, i.e. different reference systems and their fragmentation and cross-border geospatial dataset integration at national, trans-regional and trans-national scales;
- Multi-scale data integration: consistency between data with varying levels of detail; multi-resolution data and various levels of processing.
- Consistency of sets of semantic: in many cases similar concepts are designed in a slightly different way by different communities and data sources. An homogeneous access needs to be ensured and guaranteed.

All these requirements needs to be taken into account in the definition of a proper brokering architecture. The following subsections shows how this requirements are taken into account in the definition of the architecture of the brokering service in ENERGIC OD.

2.2 The Brokering Architecture

In a traditional C-S architecture, a Server provides services to the Client and each Client sends requests to the Server. In the case the same interface(s), i.e. the same application, the need to access multiple services and the interaction with these services have to be implemented in a separate way. This means that multiple standards and protocols may be implemented by the

application developer.
The brokering-oriented architecture changes this architectural style by requiring the use of a specific intermediary: the brokering layer. The broker de-couples the server and the client layers allowing the C-S separation that is crucial for accessing multiple services and Open Data developed by specific user communities. On the other hand, the effort of the application developer to access heterogeneous sources is much reduced. In fact, the brokering architecture moves the implementation of standard and protocol mediation to the brokering layer.
The C-S decoupling simplifies the interoperability requirements for both server and client components, improving scalability and flexibility. Client and server components can evolve independently and interoperability problems are solved inside the mediation layer. In particular, clients can access to the OD in the same way regardless the Server interface changes. The brokering architecture, facilitates architecture evolution of both clients and servers since all protocols and interface changes are solved by the broker. Even if the interface of a Server changes significantly, the Client access of data remain unchanged. Giving always the same interface a Virtual Hub approach give the chance to solve many interoperability problems allowing also the reuse of OD, which is one of the major concern of Public Authorities producing and delivering OD. A broker encapsulates legacy interoperability arrangements lowering entry barriers for client and servers. The Brokering-oriented architecture is a solution to implement interoperability for large scale and complex systems. For those cases a complete knowledge of all sub-systems and their services would be prohibitively expensive for an application developer.
As previously anticipated, a broker is a mediator which implements some services (i.e. discover, access, distribution, added value, etc.) to facilitate the interconnection between client and server components in a Client-Server architecture. In particular, the broker which will be developed in ENERGIC OD project will present the following functional modules (Fig. 2):

- Client request distribution in asynchronous way. This implementation is performed to allow a client to distribute requests for searching resources across more data providers. One of the major concerns is the waiting time for a query. Indeed, one of the primary disadvantage of a brokering systems is the user-perceived performance reduction (Fielding, 2000). One of the strategies to increase performance is applying shared caching at the brokering to replicate the result of an individual request such that it may be reused by later requests. Discover of OD is enabled by specific services (e.g., search engines) and by appropriate ancillary information (i.e., metadata profile ISO 19115) associated to the resources, independently from their structure.
- C-S interface protocol adaptation. This includes functionalities to match many server protocols and client ones, and vice-versa. Access services support electronic data retrieval, usually based on spatial constraints and other criteria, in forms useful for client-side processing. Supported backend for data sources access includes: OGC standard services (e.g., WMS, WFS, WCS, SOS, CSW), ESRI ArcGIS Geoportal catalog service, THREDDS, etc. In the frontend the broker can be accessed by using a JavaScript API. This API exposes the brokering functionalities (semantic discovery and dataset access) hiding its complexity. In this way an easy programming for most common operations is allowed. However, full interfaces and options to the broker are available.
- Added-value functionalities at the C-S interconnection level: The ENERGIC OD broker will implement advanced/semantic discovery. In particular, a semantic broker will automatically looks for synonyms during a search so that researches are extended. In particular, two different strategies will be used: (i) automatic query expansion, keywords are expanded automatically by the broker by interrogating a set of aligned semantic instruments (typically, controlled vocabularies, thesauri, gazetteers, and ontologies). The final result consists of a set of semantically related queries that are all executed by the discovery broker. In the (ii) user-assisted query expansion, i.e. the second discovery style, we applies the same strategy, but the semantically-related terms, retrieved from the aligned semantic instruments, are presented to users who are allowed to browse a graph developed according to these terms and select the most pertinent terms.
  Transformation module will solve for spatial inconsistencies and access data having different CRS and perform data integration in the same CRS.
  Other application services may concern results clustering resources ranking according to unified metrics, etc.
- Configurability at the C-S component level. This part allows the customization of the brokering services for each brokered client or service component.

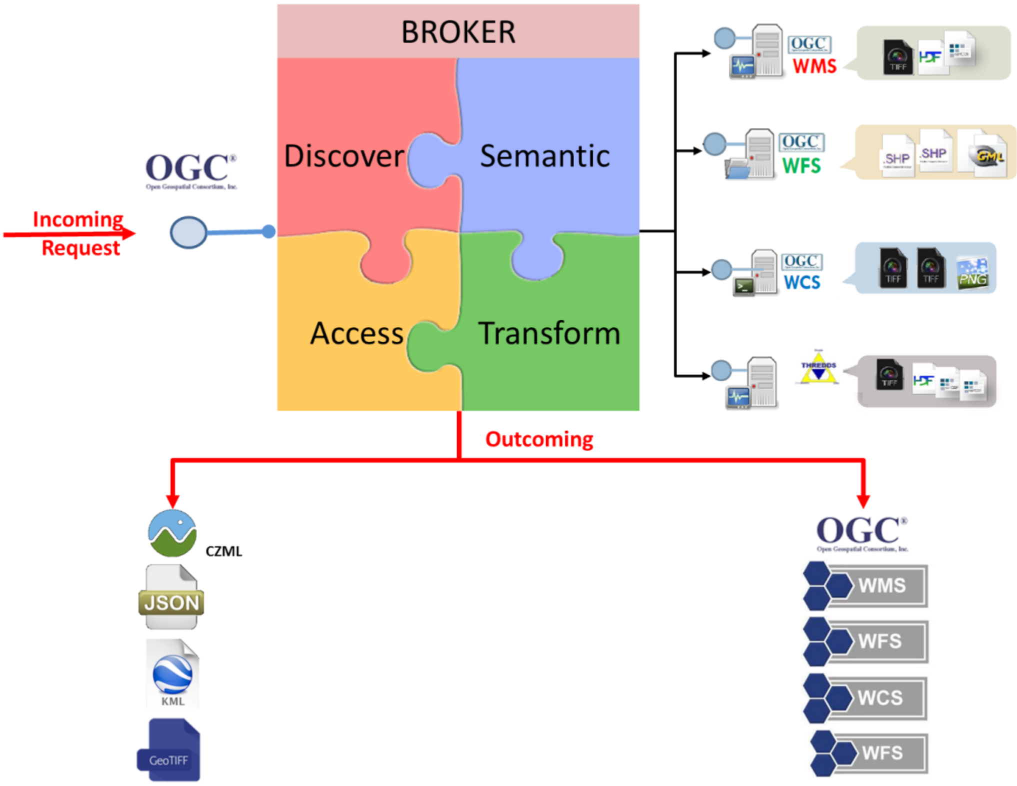

Figure 2: The broker architecture for heterogeneous data discovery and access.

As discussed, the introduction of the Brokering layer shifts the C-S architecture from a two-tier (Client-Server) to a three-tier (Client-Broker-Server) configuration. In this schema the broker may became a single point of failure. In particular, updating, governance and maintenance of the brokering are a significant problem to be evaluated. However, this is a common problem when complexity is shifted from Users and Resource Providers to the infrastructure/platform.

3 GeoPAN: development of an application based on the Virtual HUB

In the ENERGIC OD project the GeoPAN application is designed to prove the feasibility of a brokering approach for an effective wider utilization of Open Data. The purpose of this application is to combine management of historical maps in Lombardy Region (Italy) with local cartography delivered by local authorities (e.g., municipalities, regions, etc.).
Interest in the digital management of historical maps on the web has recently increased. Indeed, old maps can be of invaluable importance for a much wider range of applications, such as landscape change analysis (Azzari, Marcaccini, and Pizziolo, 1999), urban development studies (Bitelli and Gatta 2011), territorial planning (Oreni, Brumana, Scaioni, and Prandi, 2010), cultural and environmental heritage (Cuca, Brumana, Scaioni, and Oreni, 2011; Brovelli, Minghini, Giori, and Beretta, 2012) and archaeological research (Guarducci, Rombai, and Piccardi, 2011). As organizations started to upload their historical digital archives on the Internet, a series of problems arose regarding the ways data have to be processed, published and web-cataloged, leading to an established and shared process related to the utilization of ancient maps in digital format.
Modern developments in digital technologies allow a new and previously inconceivable utilization of historical maps allowing to exploit the old maps' metric information in a GIS or webGIS environment (Brumana, Oreni, Alba, Barazzetti, Cuca, and Scaioni, 2011).
The purpose of this study is to test the use of Free and Open Source software to achieve the following objectives: (i) create a webGIS for providing access to the historical maps, (ii) integrate OD in the application to enrich old historical map with modern cartographic information provided by local authorities and information for tourists (e.g., itineraries, historical information, information about point of interest), and (iii) validate the feasibility of the

brokering framework inside a Virtual Hub to access heterogeneous data. The innovation given by the brokering framework to access heterogeneous data sources in an easy way is of major importance for the GEOPAN application. Indeed, in Lombardy local authorities shares OD of local cartography using different formats and services. Indeed, while some municipalities rely on WMS and WFS, others publish ESRI© shapefiles. The Virtual Hub may give a single point of access to these data in a homogeneous way.

The results of this research should provide common map users with a new and easy way of consulting historical maps, getting the related information and stimulating tourism. The high modernization level of tools and the archive availability through the web should also enlarge the potential public with respect to the current one.

3.1 Data description

The historical cartography used to perform and evaluate the previously mentioned procedure comes from the huge collection of the Archivio di Stato di Milano and partially Archivio di Stato di Como, whose maps belong to four distinct cadastral productions: (1) the Theresian Cadaster of XVIII century; (2) the Lombardo-Veneto Cadaster of mid-XIX century and (3) its updates of 1898 (Signori, 2002); together with samples of (4) 'Impianto in conservazione' by AdT (Italian Cadastral Administration). For each cadastral series, maps are divided in sheets and are related to single municipalities. Other historical map series considered here are the 'Corografie delle Province del Regno Lombardo-Veneto'(from 1836, in scale 1:115,000), the 'Carta del Territorio del Milanese e Mantovano' (1788-1796, in scale 1:86,400), the 'Carta del Regno Lombardo Veneto' (ITM 1933, in scale 1:86,400).

Local authorities (e.g., municipalities and region) are also producing cartographic information. However, while some authorities share them as Web OD by using either OGC services or ESRI© shapefiles, others do not share cartography online. For this reason, in ENERGIC OD a survey of available cartographic information will be performed to derive a catalogue of geographic OD in Lombardy Region. This catalogue will be used as input for the Virtual Hub.

3.2 Map georeferencing

Maps were georeferenced using the procedure described in (Oreni et al. 2010). Here only the main aspects are recalled.

Each sheet was georeferenced individually with respect to the chosen grid mapping system, (Gauss-Boaga – datum Roma40 – for local cadastral maps, and UTM – datum WGS ETRF89 - for regional-territorial maps) by using an affine model. This model is a global approximate interpolator linking ground coordinates (X,Y) to image coordinates (x,y). Ground coordinates were derived from the Spatial Databases of current municipalities, which are composed of a large number of vector layers and are available at scales between 1:1,000 and 1:5,000. Ground points should be well spread in the entire raster images (Peck, and Devore, 2011). An example of point collimation on the historical cadastral map and the corresponding current cartography is shown in Figure 3.

It is very difficult to estimate and evaluate the analytical reliability, due to the non-homogeneous distribution of the error in the georeferencing process. Indeed, the georeferncing process is not only influenced by the accuracy of the two data sets but also to the scanning of maps, the deformation occurred overtime in the ancient maps, and the individuation of the persisting ground features overtime.

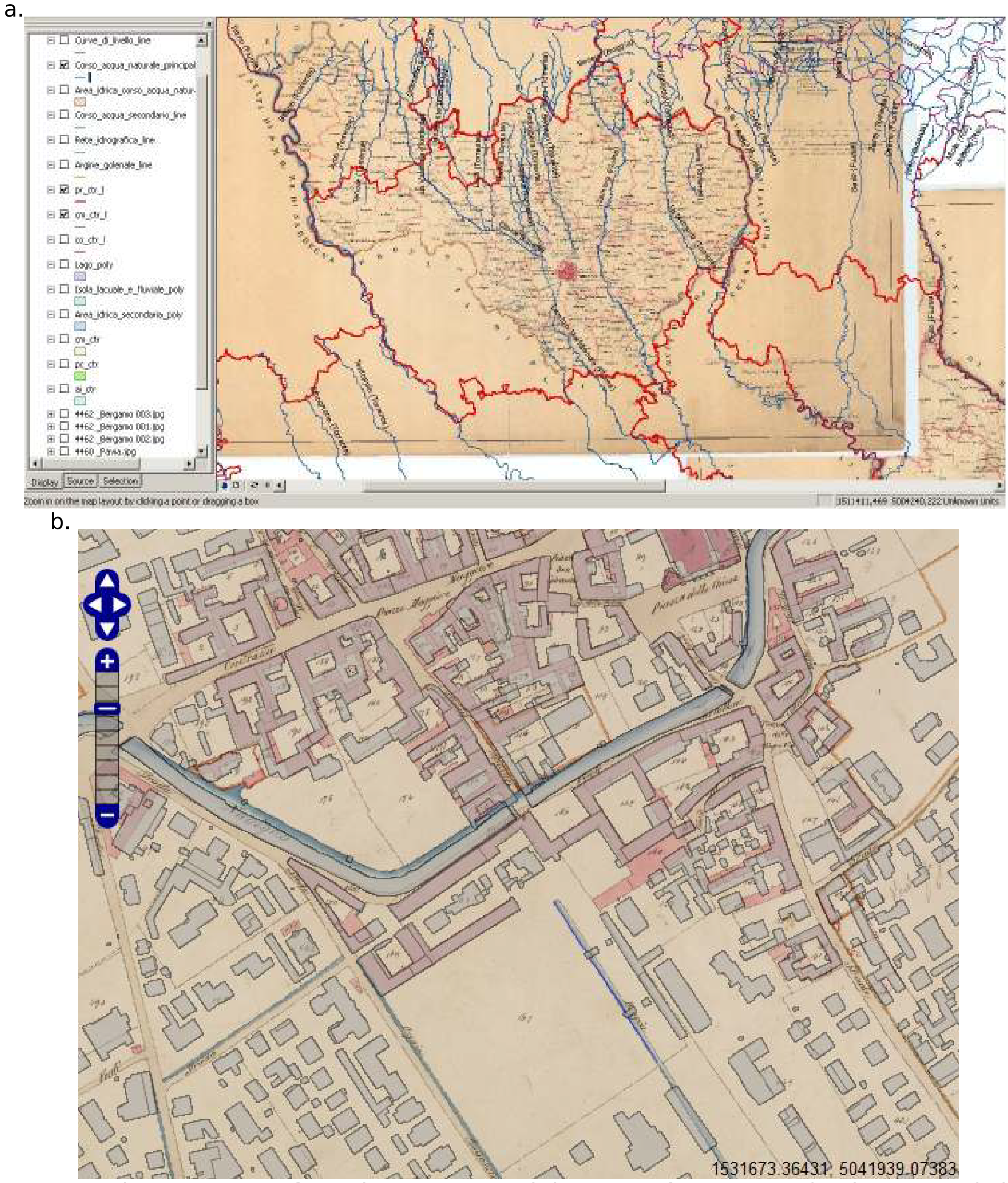

Figure 3: Ancient map georeferencing process and the vector features used to locate persisting control points.

Obviously, quantitative results of georeferencing depend on the selected number and distribution of ground points on each map (Boutoura and Livieratos, 2006). However, in the case points are well distributed in the area, the quality can be evaluated by the obtained RMSE. To have a general idea about the performance of the method it is useful to consider two extreme cases: the city center of Milan represented by the Astronomi di Brera map (39 sheets), and the 'Corografie delle Province del Regno Lombardo-Veneto'. The difference between the two is given by the fact that while in the first case it is possible to identify a large number of ground points in a very small area, while in the second case less points could be selected. In this second case, it was evident that it is impossible to use the center of the inhabited places, whose position was simply indicative, or rivers and lakes, for which it is impossible to individuate with sufficient precision correspondent ground control points, since the ancient river beds could have varied in position. The only elements that were represented in a rather precise way, being this the scope of the map, were the provincial and municipal boundaries.

3.3 Implementation of GeoPAN

A webGIS platform will be created to publish the georeferenced historical maps along with local cartographic data. As things stand at the moment, some tests and a proof of concept of the application were developed.
During the developing the web application, choices were made by paying attention to the needs and peculiarities of the project: visualization and management of large dimension raster maps, organization of cartographic resources for easy consultation, and the need of a visual impact to attract people and tourist.
Different FOSS solutions were considered for both server and client-side implementation. The server-side software used is GeoServer (http://geoserver.org), a powerful Open Source platform for publishing spatial data and interactive mapping applications on the web. GeoServer allows the visualization of produced Open Data (like touristic itineraries) through the use of an OGC standard Web Map Service (WMS). The time needed for loading and navigating these data represents the biggest challenge in accessing and displaying large raster maps in an efficient way. For this reason historical maps are released by using WMTS which is a standard protocol for serving pre-rendered georeferenced map tiles on the Internet. Indeed, for most WMS services it is not uncommon to require 1 or more CPU seconds to produce a response. In the case of massive parallel use, such CPU-intensive service is not practical. To overcome the CPU intensive on-the-fly rendering problem, WMTS allows for using pre-rendered map tiles.
In the general architecture of the service the Virtual Hub will be used to access local cartographic information. Figure 4 shows two possible architectures of the GeoPAN app with and without the Virtual Hub. The architecture with the VH gives a simpler access to geographic OD giving a single point of access with a standard protocol and interface.

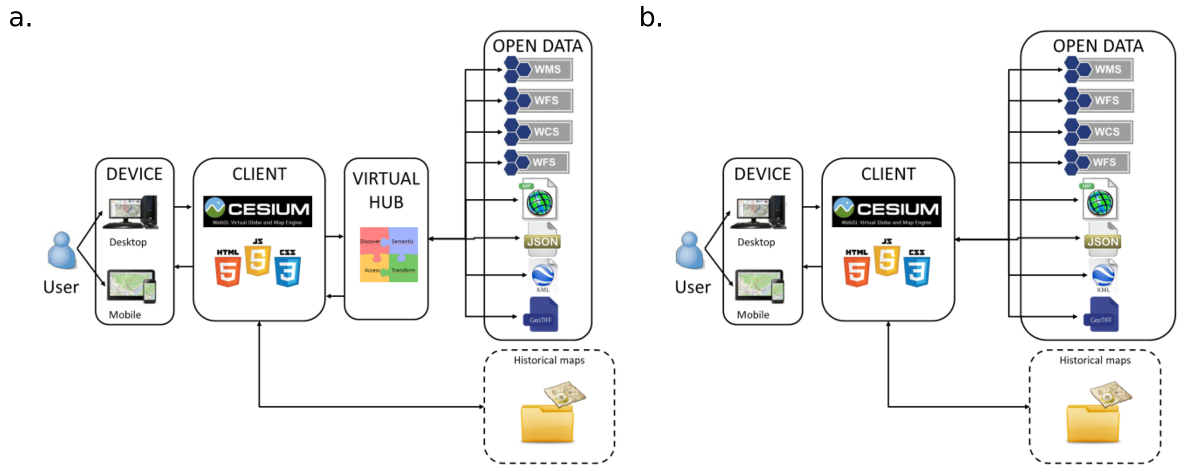

Figure 4: Two possible architectures for the GeoPAN app: (a) with and without (b) the Virtual Hub. An architecture with the Virtual Hub all interoperability problems are solved by the Virtual Hub. An architecture without the Virtual Hub would require to solve several interoperability problems at client side.

To develop the client-side of the system Cesium (http://cesiumjs.org). Cesium is a JavaScript library for creating 3D globes and 2D maps in a web browser without a plugin. It uses WebGL for hardware-accelerated graphics, and is cross-platform, cross-browser, and tuned for dynamic-data visualization. Cesium is supported by Android, iOS and Window tablet. It is delivered under the Apache 2.0 license, which means Cesium is free for commercial and non-commercial uses. Today Cesium support the following geospatial features:

- Map layers: WMS, TMS, WMTS, OpenStreetMap, Bing Maps, ArcGIS Map Server;
- Global terrain: quantized mesh, ArcGIS Image;
- Vector data: CZML, GeoJSON, TopoJSON, KML (announced for March 2); and
- 3D models: glTF (on-line and off-line converter from COLLADA available).

The great advantage of Cesium is the opportunity to visualize maps and contents over a Virtual Globe. It gives an interesting approach to the old maps and can attract more the people's attention in a way similar to Google Earth©. Cesium allows also great freedom in developing

the web application structure and layout (Figure 5).
As the proof of concept is the actual implementation, the graphical interface of GeoPAN is under development. The GeoPAN web client consists of two parts: a layer menu and a main map panel. The layer menu itself is additionally divided into two parts: the first one allows users to view and select all the georeferenced historical maps which are ordered in two separate trees, the second one will be developed to interact with the Virtual Hub formulating queries and displaying results.

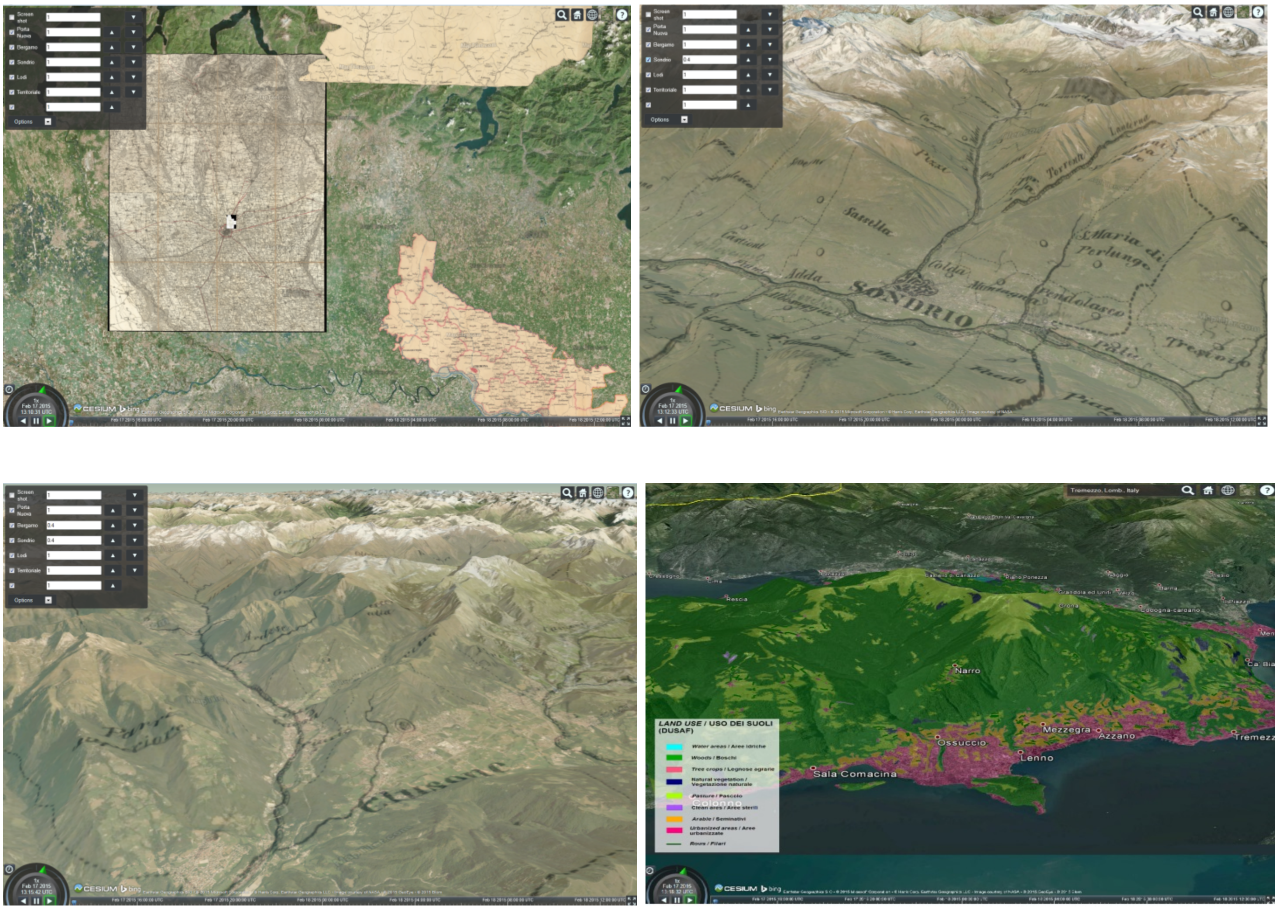

Figure 5: Some ancient map georeferenced in GeoPAN interface and a land use layer.

4 Conclusion

ENERGIC OD tries to lower User and Data Producers entry barriers for fruitful exploitation of OD for service production to citizens and Public Administrations. To achieve this goal, the brokering approach adopted by Virtual Hubs can offer the opportunity to support existing and independent infrastructure and OD initiatives (supplementing and not supplanting them). In the brokering approach the data heterogeneity is faced introducing a mediator which separates the client and server layers implementing brokering services (i.e., mediation, distribution, added value, etc.) and facilitating the interconnection between client and server components. What is most important in moving toward a Broker-based infrastructure is the greater level of flexibility than other architectural solutions. This gives the possibility to integrate not only traditional geographic information, but also cultural, social and economic information. The brokering-oriented style was successfully implemented and demonstrated by the EuroGEOSS project. This experience has shown that the Brokering approach is mature to discover and access information useful in the scientific world without the need of scientific users to implement standard and protocols. The aim of the ENERGIC OD project is to demonstrate that the same approach can be used also for the wider community of web service developers. In particular, this architecture may help them in accessing OD using a single interface. GeoPAN tries to prove this concept. The decision of publishing historical maps was taken with the aim of providing a synthetic and continuous vision of the territory, at different historical levels, in order to allow different users to make immediate comparisons between the shapes and the characteristics of the landscape of yesterday and today. To this aim, current cartographic information accessed with the broker is of primary importance. This service may also convey touristic information along with ancient maps giving the opportunity to attract tourist to the different landscape levels and providing virtual and on site itineraries. Unfortunately, only few municipality allows for publication of geospatial OD.

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