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SEMANTIC SELECTION OF GEOREFERENCING SERVICES FOR URBAN MANAGEMENT

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SUMMARY: *Geocoding has become one of the most popular on-line services. Nowadays, there exist many Web Services providing geocoding functionality which differ not only in technological aspects (interface, invocation style, etc.) or terms of use, but also in type of geographic information provided and spatial data quality. Currently, there is no problem to find geocoding providers but to choose the proper one, which is determined by user's requirements. The public administration is responsible for providing the official and appropriate information for citizens or deal with risk and health management issues; therefore, urban management systems require geocoding services of high quality in terms of quality of service (QoS) and spatial data. However, the present Web geocoding public market is dominated by geocoding services for average users, i.e. users that can accept low QoS or are not interested in the lineage of data. In this situation, a compound geocoder can join data from several services of geographic information and provide services oriented to the users that demand high quality, for example urban management systems. This paper presents an architectural approach for adaptive compound geocoding Web services built on diverse Web services of geographic information, such as gazetteers, cadastral services and address geocoding services. The proposed architecture is characterized by extensibility and adaptivity thanks to application of the ontologies (Administrative Unit Applied Ontology of Spain and Service Characteristic Ontology) and advances in Semantic Web related to strategies for source selection and result data evaluation, which are introduced in some details. As an example of real use case, it is presented the implementation of address geocoding compound Web service whose instances are applied in diverse tasks in urban management systems of Zaragoza City council in Spain.*

KEYWORDS: *Geocoding, Ontology, Service Architecture, Web Service.*

REFERENCE: *Florczyk A J, López-Pellicer F J, Muro-Medrano P, Nogueras-Iso J, Zarazaga-Soria F J (2010) Semantic selection of georeferencing services for urban management, Special Issue Bringing Urban Ontologies into Practice, Journal of Information Technology in Construction (ITcon), Vol. 15, pg. 111-121, http://www.itcon.org/2010/8*

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1. INTRODUCTION

Public authorities charged with the responsibility of dealing with the maintenance of public infrastructure require urban management systems able to manage large amount of resources. Especially in case of emergency situations (e.g. floods, fires), an effective management of the resources included in the emergency plan involves a centralized and coordinated management system. These systems often require the support from Geographic Information Systems (GIS) for street address geocoding. Additionally, information published on the local administration portals is the reference point of knowledge for citizens. Thus, independently of application, there is a need for up-to-date data of high quality (e.g. coverage at the national level, high precision, reliability). However, assurance of data quality is a hard task. The decentralized public administration is responsible for data maintenance, and the spatial information changes continuously, especially in the urban area (e.g. cadastral data). In this paper, geocoding means the act of turning descriptive locational data such as a postal address or a named place into an absolute geographic reference (Goldberg et al, 2007). This includes relative description of location as input data (Hutchinson and Veenendall, 2005), and any geographic description as the output, i.e. a point, a polygon or three-dimensional geospatial entity (Beal, 2003).

The most prevalent way of providing geocoding functionality is a geocoding service. Nowadays there are lots of geocoding services with diverse characteristics determined by the quality of geo-service, the provided data and the terms of service (ToS). Today there is no problem in using on-line geocoding providers but to find and to choose a proper provider. The main differences among geocoding Web services are caused by the provided data, i.e. the type of content (e.g. point of interest, address). The quality of geo-service is influenced by factors that depend on the typical QoS requirements (e.g. response time, reliability) and the quality of the spatial data. The geocoding services also differ in their ToS. In general, regardless of service origin, which might be private sector (e.g. Google, ViaMichelin or Yahoo), public sector or volunteer communities (e.g. GeoNames, http://www.geonames.org/, Geograph British Isles, http://www.geograph.org.uk/, OpenStreetMap, http://www.openstreetmap.org/), the services may be divided into three groups due to their ToS: paid access services, free of charge services with restricted use, and services of free use. The private sector offers the ad-hoc designed paid services, which guarantee the quality of data and service. Free services offered by the public sector or open communities provide less quality than the dedicated ones. Usually, the largest providers offer free access to their address geocoding services with lower quality and some use restrictions. Their ToS restrict the presentation (e.g. the license requires use of the supplier's visualization APIs), prohibit the reuse of data, and have influence on the quality of applications based on that service, i.e. establishing limits, such as rate limit or the maximum number of requests per day. Finally, we should also consider that new types of geocoding service applications such as support of mobile application, demand supplementary characteristics. Location-based services require the support of geocoding services for tracking of user location and the reverse geocoding at the operation system level (e.g. the Android, http://developer.android.com/index.html, or GeoClue, http://www.freedesktop.org/wiki/Software/GeoClue, projects). The availability and capabilities of these services have to be adjusted to the requirements of mobile devices (e.g. battery life, cellular network, access to the Web, or GPS availability).

The choice of service is determined by the use case. Free geocoding Web services are appropriate for "geotagging", i.e. the process of adding the geocoded information to any kind of media, the local news or incidents (e.g. water supply shortage, planned roadwork) because such information does not require high quality geocoding services or spatial data. On the other hand, the systems on which depend public health (Bonner et al, 2003), public security (Ratcliffe, 2004) or environmental services (Ratcliffe, 2001) require high quality of service and data. For example, quickness and efficacy of fire-fighters depend on the information they possess such as the characteristics of the building in fire (e.g. number of floors, shape, location of entrances and the accessibility, nearby buildings) or the localization of fire hydrants.

The vast heterogeneity of geocoding services and the specific features of geographic data set up the open problem of provider selection. There are many works in the context of the service discovery and selection. Some of proposals need prior service evaluation, e.g. rating agency (Sriharee, 2006) or user (Manikrao and Prabhakar, 2005) pre-evaluation, but most of the works in this area use typical QoS features (Yu and Jay Lin, 2005, Wang et al, 2006, Tsesmetzis et al, 2006), for instance, end-to-end delay, overall cost, service reliability, availability.

Recently, researchers show interest in services of geographic information (Fallahi et al, 2008, Lan and Huang, 2007) but they include only basic concepts (e.g. coverage) and do not exploit specific characteristics of geographic data in discovery and selection processes (e.g. reasoning based on coverage, quality of geographic objects).

Our proposal for compound geocoding architecture attempts to be a first step in the research on the problem of the geocoding service selection via geo-ontologies. This approach uses a framework that allows building hybrid solutions composed of different services which provide geographic information (e.g. geocoding, gazetteer or cadastral service). Each solution applies Administrative Unit Ontology, AUO (López-Pellicer et al, 2008) for (i) provider selection and (ii) data integration. This approach may increase the flexibility and adaptability of applications. In case of the public services, it provides access to different services, national and local, in a transparent manner and ensures the use of updated data.

Existing geocoding services are generally limited to assign a geographic coordinate to an absolute location such as a street address. However, urban management systems need to geocode location description in a more flexible way. For example, it is common that a citizen who calls an emergency centre does not know the address where he/she is and the descriptive information that provides is ambiguous or even confusing (e.g. “100 meters of a memorial statue in the park, which is situated by Colon street”). In such a situation the user needs to be “geolocated”.

Hutchinson and Veenendaal (2005) define “geolocating” as the evolution of the geocoding process that permits to assign valid geographic codes to freeform textual descriptions of locations. Conventional geocoding services that work with absolute locations will not be able to determine the coordinates of the place of incident. The best solution is a geolocating service, which might interpret correctly the relative location (e.g. distance, direction), with landmarks (e.g. park, railway station) and features (e.g. coffee shop). That implies query syntax flexibility, user interaction, user context consciousness and complex site representation. It is important to stress that the authors argue for a new methodology but they do not include details of how could be implemented.

The main design goals of the architecture presented in the following sections are flexibility and extension facility. Due to the fact that the geolocating process demands spatial information of wide range of types, the compound approach seems to be suitable for the architecture model of a geolocating system. This approach aims to develop a baseline for designing core components such system.

The rest of the paper is organized as follows. Section 2 presents features of georeferencing services which are used as semantic annotations for service description. Then, the proposed architecture is presented. Section 4 presents the state of the art in geocoding of urban management applications in Spain. Then, an example of implementation of the proposed architecture is detailed with the practical use case in urban management where an instance of implemented service is applied. Finally, some conclusions are drawn and future work is outlined.

2. CHARACTERISTICS OF GEOREFERENCING SERVICES

The proposed architecture allows the service selection according to the use case requirements. Therefore, the proper description of each source is vital for the behaviour of the whole system. Fig.1 presents the features to consider during the provider evaluation. The obtained values are provided in RDF files with corresponding semantic annotations. These values are essential for the service selection and the decision making process.

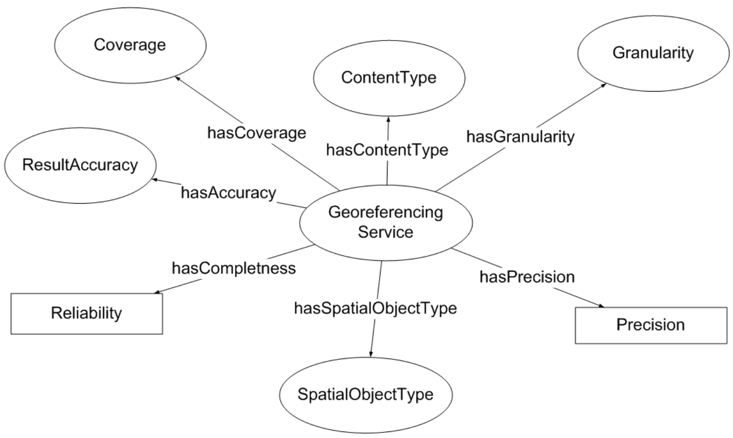

FIG. 1: Characteristics of georeferencing service (precision and reliability as numeric values).

The main features of each geocoding service are (1) *the coverage*, (2) *the type of content* and (3) *the type of spatial object*. The first two of them are always given by the provider or are indicated by the name of the service. The first one defines the area in which offered data are situated. Usually, this area corresponds with the unit or set of units from political division of territory, as the majority of georeferencing Web services are provided by public administrations from local and central level. One of the territory organization ontology is the AUO based on political division of territory. Using instances of classes which are specializations of *jurisdictional geographic object* concept from AUO as value of the coverage permits to reason on the semantic relations among them rather then relying on their spatial objects. For example, the province of Zaragoza has a set of municipality members and is part of Spain. All municipalities which belongs to Zaragoza province are also members of the Aragon Autonomous Community. In case of searching for the services that provide data from region of province of Zaragoza, system will also consider those services which coverage equals to Aragon, Spain or the world, or even might return a set of services which coverage combination corresponds to the required coverage, e.g. local services of all municipalities of province of Zaragoza.

The type of content strictly depends on the types of geographic feature provided by service. The last one indicates the list of provided types of spatial object, such as point, polygon or 3D entity. For example, the Cadastre Service of Spain (*Servicio de Catastro de España*), http://ovc.catastro.meh.es/, as the name of the Web service indicates, has the coverage of Spain and offers coordinates of parcels. Google Maps has world coverage and its type of content is street address geocoded via point, which is provided by the service description.

From the analysis of spatial data, it is possible to obtain two additional indicators (of range 0 – 1): (5) *the reliability* and (6) *the precision*. The reliability indicates the capacity of representation of elements of physical world by the content. The service that offers all elements of real world has a reliability value equal to *'1'* (100%). The indicator of precision informs about the average positional error (Christen et al, 2004) of the whole dataset. It is important to note that this indicator may be influenced by difference between the provided spatial object and the search one. For example, using cadastral data for the address geocoding, there will be a decrease in spatial data precision.

Frequently, the reliability and / or the precision of spatial content can vary in function of the area of relevance, for example new suburbs might be even omitted. Such feature, called *the granularity*, might be obtained from the exhaustive evaluation of spatial content along with its semantic analysis (e.g. distinguishing types of geographic features as: cities of population more than 500.000, cities of population more than 100.000, towns of population more than 10.000, villages, and hamlets).

One of the useful features introduced for purpose of the proposed architecture is (4) *the result accuracy*. It should not be misinterpreted as “data accuracy”, the term commonly used in literature to describe positional accuracy. Result accuracy is estimated for each source via analysis of the source data model and the application domain model. It indicates the capacity of source to fulfil the domain model, and is represented via the last domain model field which the source might score.

An example of a service characteristics file presented by the RDF graph (Fig. 2) describes the Cadastre Service of Spain. The process of evaluation of this service is designated for a system dedicated to address geocoding.

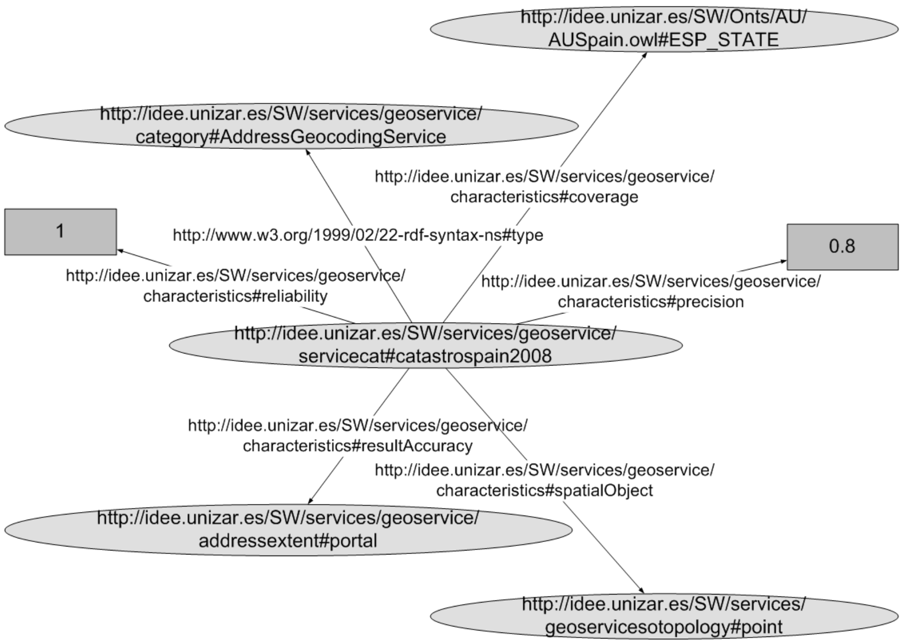

FIG. 2: An RDF graph describing the Cadastre Service of Spain.

3. ARCHITECTURE OVERVIEW

The compound geocoding architecture can use different sources of geographic information, such as gazetteer, street data, geocoding or cadastral services. Each source has to be described in terms of the introduced characteristics of georeferencing service which values are provided as semantic annotation of service. The proper description of sources is vital for behaviour of whole system due to the fact, that the obtained values are used as the clues for source selection, which determines the adequate functionality of the system.

The result accuracy feature is defined via comparison of the application domain model of searched information with the response data model of the service. This requires a well defined domain model or a set of them. To simplify the data integration tasks all data models, domain and source data models, should be described with help of one domain ontology.

The main elements of the compound geocoding architecture (see Fig. 3) are *the input data processor*, *the core* and *the mediator component*. The Input data processor component is responsible for performing the pre-processing of text from the input data. The steps in this phase of geocoding are common techniques among geocoders (Hutchinson and Veenendall, 2005): cleaning, parsing and standardizing.

The core component is responsible for the whole process of source selection (s*ource selector*) and result data evaluation (*data evaluator*). The source selection task is based on rules implemented in *the decision maker*. These rules apply several search criteria (*search criterion*) to reason on the source annotations (*service characteristics*, *SCs*) obtained from previous tests as described in section 2 of this paper. Search criteria are also defined in the terms of the service features and they might be provided by (1) the application context (*search profile*) and / or (2) the user requirements as part of the input data. An example of search criterion is:

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hasCoverage(Zaragoza-Province) and hasPrecision > 0.9 and hasReliability > 0.5
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The strategy of services selection can relax rules of the search constraints, e.g. by decreasing the value of precision and / or reliability, if there is not available any service which conforms to the requirements or the response data are not satisfactory.

The mediator component consists of pluggable *service connectors* and the *data integration component*. The main advantage of the connectors is the abstraction from used communication protocol, invocation styles or interfaces. The data integration component is responsible for data harmonization which consists of data models mapping and, if it is required, coordinate transformation.

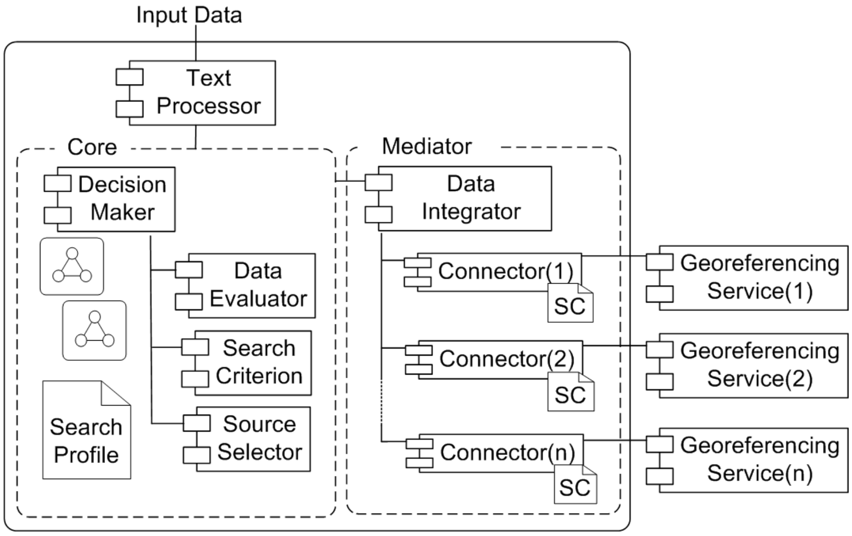

FIG. 3: Compound Geocoding Service Architecture.

This architecture allows geocoding different types of named places, and, due to complementing data from one source with data from others, improves the reliability and the precision of result. It also gives the user more freedom in deciding the search strategy. Accessing several services permits to decide in runtime the search strategy, for example, the best response of the entire system, the best answer for each source or the best answers from a chosen source. In addition, as the details of implementation are hidden in the mediator, this allows incorporating any type of geographic information.

4. ADDRESS GEOCODING IN URBAN MANAGEMENT IN SPAIN

Public authorities need geocoding tools for diverse applications. On the one hand, the official Web pages publish geocoded information and become an important source of centralized knowledge for citizens. In this case, result data obtained via the usage of geocoding services of low quality are satisfactory. The same services are not appropriate for the urban management systems that support the public services of civil protection (heath centres, fire-fighters). Especially, the systems that manage emergency situation (e.g. floods) require from Geographic Information Systems up-to-date data of high quality (state coverage, reliability, high precision).

In the public sector in Spain, the task of providing spatial data appropriate for urban management systems is rather tough. The responsibility for maintenance of the urban content is decentralized, however the decision about publication of spatial data of new urban areas is taken earlier at state level, which is reflected in central government datasets. As a result, local administration has data of the highest precision but of lower reliability, when, compared to the services that use the content of central government, e.g. the Cadastre Service of Spain.

There are some proposals of geocoding services supported by public authorities at state level, e.g. the Cadastre Service of Spain or CartoCiudad services, http://www.cartociudad.es/visor/. The first one is characterized by the best reliability among the other existing geocoding services at state level in Spain, but, due to the fact that its content type is parcel, the precision for address geocoding is decreased. The CartoCiudad combines the spatial contents provided by diverse public institutions (i.e. General Direction of Cadastre, Postal Office, National Institute of Statistic, and General Direction of National Institute of Geography) and from local authorities. The main disadvantage of the CartoCiudad services is the lack of the update procedure and gaps in coverage. Additionally, both these proposals share the problem of the uncomfortable search as it is necessary to indicate the search area (province and municipality) and requires the definition of work-flow for address geocoding.

It is more common to find Web Services offered by local authorities at their portals, e.g. the Street Data Web Service of Zaragoza city council (IDEZar SG). These services are characterized by a high data precision. However, their granularity may vary depending on the area (i.e. urban centre, village) and, usually, there are lacks in coverage in areas such as motorways or new urban zones.

5. USE CASE: GEOCODING SERVICES FOR URBAN MANAGEMENT

Zaragoza is the fifth largest metropolitan area of Spain with 783,763 habitants according to the INE (2006) and the area of Zaragoza city is more than 1000 km^2 and with the population of more than 620.000 citizens. The urban management systems of the local administration of Zaragoza municipality require address geocoding functionality in numerous applications and tasks from diverse areas, such as management of local incidents (e.g. traffic cuts, water or electric supply shortage), event management (e.g. demonstration, match or concert), street map of local administration portal (council of Zaragoza) or Web service to support the point of interest guide for mobile devices. All those applications have to deal with the problems presented in section 4. The proposed architecture targets to overcome them. The implementation of a generic compound geocoding service provides instances which might be used in diverse applications of different requirements. These instances adapt to each environment according to the constraints provided by the search profile. This approach reduces significantly the development costs and improves reliability and precision of response.

The implemented compound service for address geocoding in Zaragoza municipal area uses the following services: the Cadastre Service of Spain, set of CartoCiudad services, Google geocoding service and IDEZar SG service. As it is explained in the following paragraphs, the first step consists of extending the Administration Unit Ontology of Spain, AUSpain (López-Pellicer et al, 2008) with individuals from Aragon scope (e.g., the municipality of Zaragoza, province of Teruel, comarca of Aranda etc.), then, the address domain model is identified. Afterwards, each source is being evaluated and described, which produces a set of RDF files.

The domain ontology of the AUSpain ontology is the application of the AUO, therefore the introduced individuals, which represent the units of territorial division, might be used as the coverage description of service. Additionally, as addresses are bound to political organization of the territory, the concepts of the AUSpain ontology were applied for data integration via mapping process. According to the general approach (Walker, 2008), the data model of the street address in Spain contains at least *province*, *locality*, *zip code*, *street address* (street name, portal number and other elements as floor or letter of door). Most of the Web services that might be used as street address source do not provide zip code. Thus, the main address data model has been extended (*autonomous community* and *comarca*) and modified to disambiguate the search results (*municipality* and *district*). As this implementation is dedicated for the municipality of Zaragoza, it is possible to initialize some fields of domain model, and the default values are used to restrict the results from sources during the data integration process. The Fig. 4 presents overview of the applied domain data model and its evolution. Fig. 5 and Fig. 6 present the application domain model and the source models mapping. The data model of the CartoCiudad and the Cadastre services are simplified and presets only the address part obtained from requesting various services as defined in work-flows.

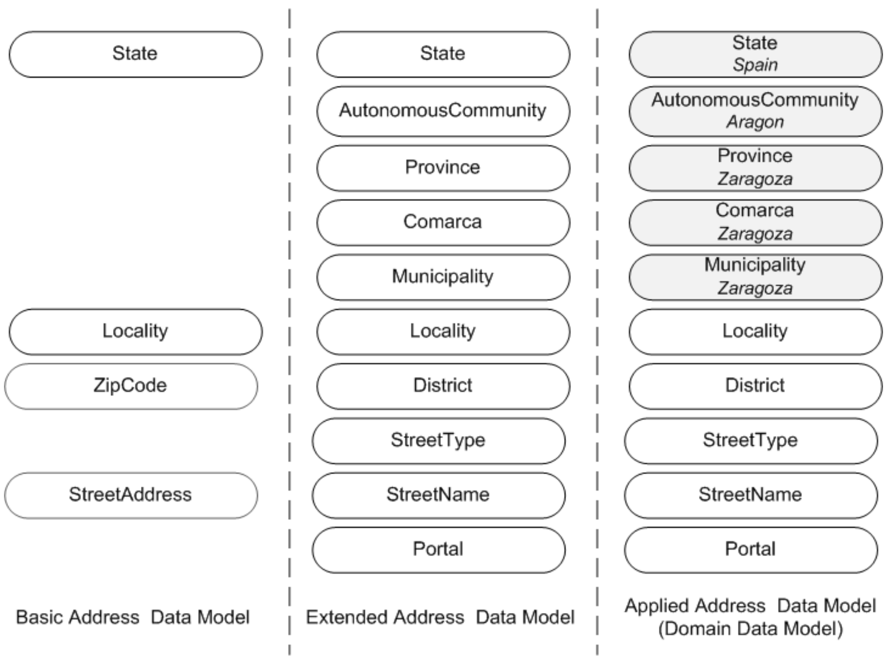

FIG. 4: Domain data model evolution.

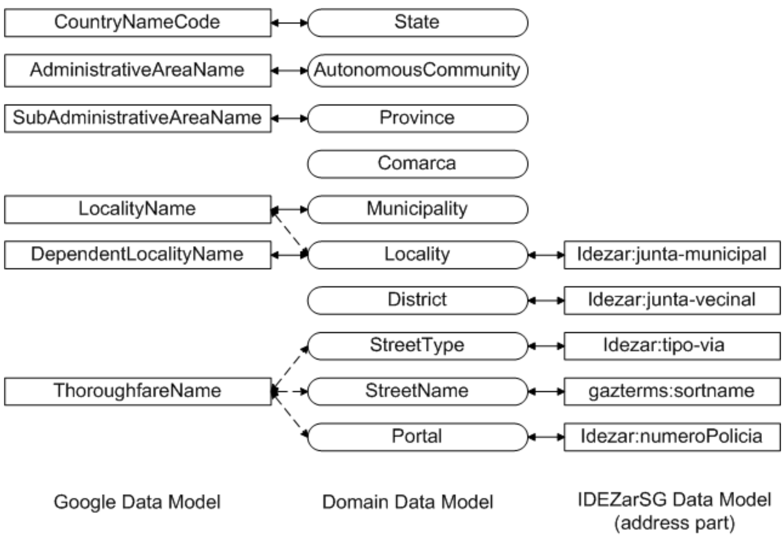

FIG. 5: Mapping domain data model to data models of Google and IDEZarSG services.

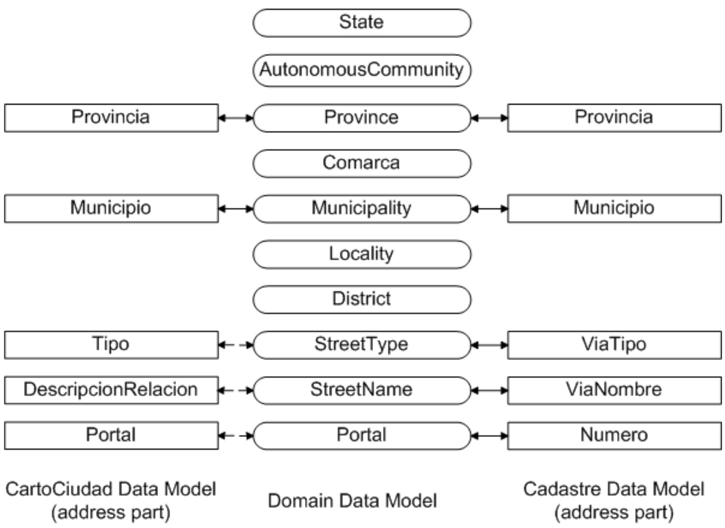

FIG. 6: Mapping domain data model to data models of CartoCiudad and Cadastre services.

The service features considered by this implementation are the coverage, the precision, the reliability and the result accuracy. The rest of the features described in this paper are omitted in the selection strategy due to the fact that all used sources provide points as spatial objects and the searched information is of one type (street address).

Determination of values of the basic service features, such as coverage and the spatial object, requires the analysis of service online documentation. The reliability and the precision metrics are obtained from a set of evaluation tests performed against reference datasets. The choice of the reference datasets is of great importance. The Cadastre Service of Spain, being the official land and property registry, has been taken as the reference dataset of the reliability tests. The IDEZar SG service is characterized by high quality and its coverage corresponds with the target application coverage. Therefore this service has been chosen for the precision reference dataset. The values of reliability and precision are obtained using statistical methods: the reliability is calculated on base of the average hit error and precision on base of the mean square error. The result accuracy is obtained from the data models mapping. Tab. 1 shows values used in this implementation.

TABLE 1: Evaluation of used Web services.

	Coverage	***Reliability***	***Precision***	***ResultAccuracy***
IDEZarSG Service	Municipality of Zaragoza	0,98	1 (reference source)	Portal
GoogleMaps Service	World	0,96	0,99	Portal
Cadastre Service of Spain	Spain	1 (reference source)	0,85	Portal
CartoCiudad services	Spain	0,90	0,98	Portal

The developed service has been applied as a generic component in the urban management systems of the Zaragoza city council. The instances of this service are dedicated for diverse applications whose requirements are stated by the profile descriptors. Fig. 7 shows an overall view of the compound architecture of geocoding service and some examples of types of client applications that use the service. The unified access to georeferencing Web services (e.g. the Cadastre Service) is offered by connectors that implement the *AdvancedGeocoder* interface and hide the request work-flow in case of the Cadastre and the CartoCiudad services. This interface is implemented also by the *Geocode Wrapper* which accesses INE local database, the information about the census area units in Spain. The data are stored locally due to the fact that it is not provided through any Web service and the data must be downloaded as CSV files from National Statistics Institute Web page (*Instituto Nacional de Estadística*, INE), http://www.ine.es/. As the INE information is official and complete therefore is used as reference point in case of the result data ambiguity. The cache component improves the performance of the system and the logger (*Log*) permits tracking its behaviour and offers feedback information on user request profile which is valuable hint in the cache strategy. The simplified *BasicGeocoder* interface is offered via HTTP protocol and it is the request point for the majority of the client applications.

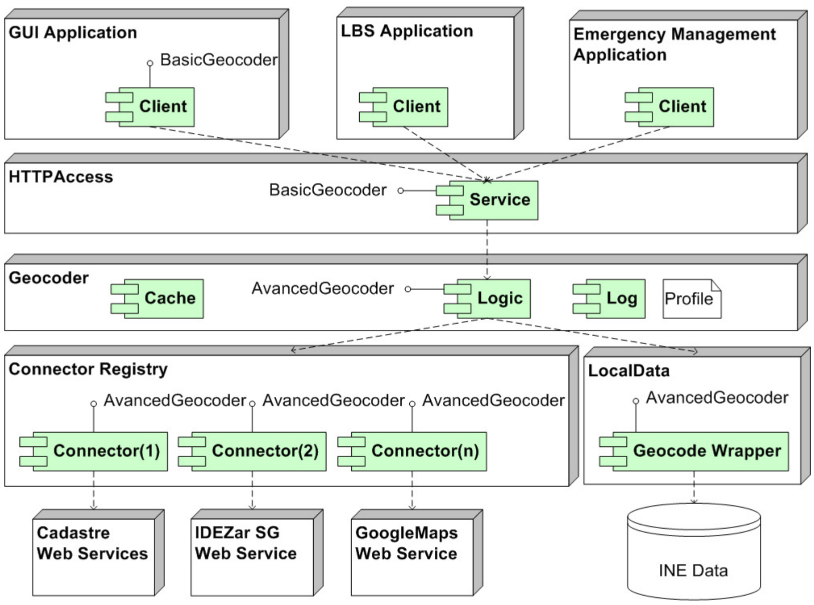

FIG. 7: Layer view of the compound geocoding service and client components.

An example of these applications is the system to support management of local incidents in Zaragoza locality used by the city council. This system is used by the council workers to introduce the local incident information, which is provided to citizens via an official web portal. Fig. 8 shows the general overview of the application architecture along with the screenshots of its GUI components. The form of the *Input Component* allows the user to introduce a new incident and the results of address geocoding are presented as an ordered list ordered via recommendation based on street name and type matching. The selected, normalized street address, its spatial coordinates (a point) and information about the incident (time interval, incident type, etc.) are saved in the local incident database, that is then used by the GeoRSS service, which publish new information on inscription lists. This information might be also visualized on the local incident map of the official Web page of Zaragoza city council.

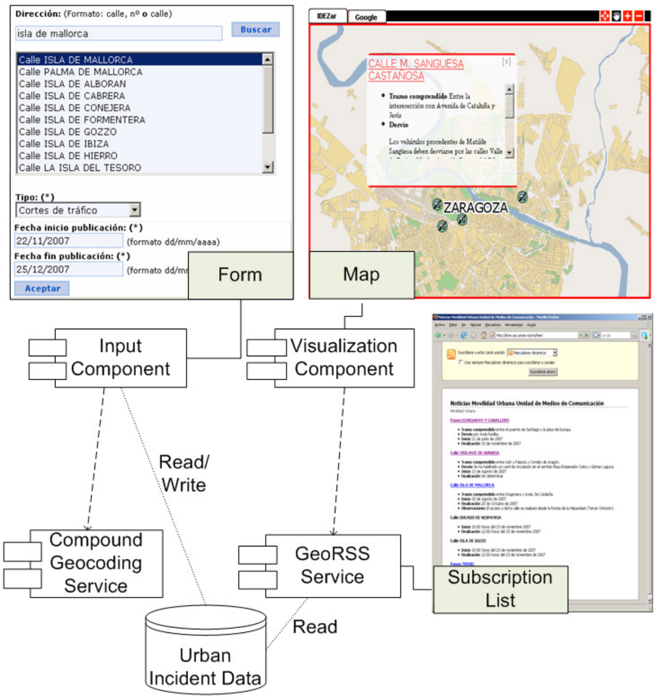

FIG. 8: Introduction and publication of urban incidents.

6. CONCLUSION AND FUTURE WORK

This paper has presented the problem of georeferencing service selection and an approach to solve this problem based on a compound geocoding architecture. We have detected that the main issue in this approach is the selection and measuring of selection indicators. The main design goals of the proposed architecture are flexibility and extension facility. The advanced application of geocoding, i.e. geolocating which deal with free form textual description of location, demands spatial information of wide range of types. Therefore, the compound approach seems to be suitable for the architectural model of a geolocating system.

Future work will be focused on the development of an appropriate methodology for the evaluation of georeferencing services with stress on its automation. The question of the granularity evaluation requires special attention. The statistical methods applied to evaluate the responses will be studied more deeply. With this information, it would be feasible to develop techniques for comparing different services of georeferencing.

As the main disadvantage of the proposed approach is the high cost of the implementation of the connectors, future work will focus on this issue as well. In this context, efforts will be devoted to employ the recent advances in the research on service interoperability, ontology alignment and reasoning.

7. ACKNOWLEDGEMENTS

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