SDI-Based Business Processes: A Territorial Analysis Web Information System in Spain

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Abstract

Spatial Data Infrastructures (SDIs) provide access to geospatial data and operations through interoperable Web services. These data and operations can be chained to set up specialized geospatial business processes, and these processes can give support to different applications. End users can benefit from these applications, while experts can integrate the Web services in their own business processes and developments. This paper presents an SDI-based territorial analysis Web information system for Spain, which gives access to land cover, topography and elevation data, as well as to a number of interoperable geospatial operations by means of a Web Processing Service (WPS). Several examples illustrate how different territorial analysis business processes are supported. The system has been established by the Spanish National SDI (*Infraestructura de Datos Espaciales de España*, IDEE) both as an experimental platform for geoscientists and geoinformation system developers, and as a mechanism to contribute to the Spanish citizens knowledge about their territory.

Keywords: Spatial Data Infrastructure, Geospatial Business Process, Web Information System, Web Service

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1. Introduction

Spatial Data Infrastructures (SDIs) are large, distributed spatial information systems which intend to provide support to spatial data applications in different sectors. They are composed of people, policies and agreements, standards, data and technologies and are commonly headed by public administrations. One of the roles of SDIs is contributing to the spatial enablement of societies and governments by providing a supporting platform (Nogueras-Iso et al., 2004; Rajabifard, 2008; Masser et al., 2008). This support can be used to provide information services to citizens and for citizen empowerment (Georgiadou and Stoter, 2008), or to facilitate their relationship with the public administrations (Latre et al., 2010).

A possible strategy to leverage SDIs to support the spatial enablement of a society is by providing specialized Web applications which make use of *SDI services*[1], like for instance those related to risk management described by Mansourian et al. (2006); Molina and Bayarri (2011). These Web applications can give access to geospatial knowledge and tools even to the general public, while the SDI services can be accessed by more specialized users who could include them in their own geospatial business processes. These SDI services should provide, among other things, access to land cover and elevation data as they are important inputs in geoscience models and analyses as diverse as landscape dynamics (Serra et al., 2008), forest dynamics (Freitas et al., 2010; Geri et al., 2010) soil depth modeling (Tesfa et al., 2008) and species distribution modeling (Illán et al., 2010).

SDI services typically support the spatial data search, visualization and download functionalities suggested by GSDI Technical Working Group and contributors (2004). These services are usually specified in standards developed by the United States Federal Geographic Data Committee (FGDC), the International Organization for the Standardization (ISO) and the Open Geospatial Consortium (OGC), for instance as proposed by Nebert et al. (2007). Several authors have been pointing out the necessity to include also other *spatial Web service*[2] types in SDIs for some time (Bernard and Craglia, 2005). Among them it would be fundamental to consider the OGC Web Processing Service (WPS) specification (Schut, 2007), which has been evaluated

[1] Web services deployed in an SDI. They usually follow OGC/ISO specifications, but an SDI may use other standards too.

[2] A Web service which provides access to, or allows processing of, spatial data.

and found appropriate to encapsulate geoprocessing as a Web service (Kiehle, 2006; Michaelis and Ames, 2009).

Many geospatial Web applications have been built on *OGC Web services*[3]. For instance, Salvati et al. (2009) describe a Web GIS that uses OGC Web Map Services (WMS) (de la Beaujardiere, 2004) to publish information about historical landslides and floods in Umbria, Italy. Han et al. (2008) go a step beyond including Web service based analysis functionalities; this system uses several OGC Web service types, although for the analysis Web services they use the Simple Object Access Protocol (SOAP) (Gudgin et al., 2007). Gebhardt et al. (2010) have developed a Web water information system for the Mekong delta, in Vietnam, that uses different types of OGC Web services including Web Processing Services for the analysis, though their paper is more focused on the data models and semantic aspects of their system. Besides this, WPSs have been used to publish geoscientific data and algorithms (Li et al., 2010), and to set up complex geospatial analysis business processes to monitor water quality (Álvarez-Robles et al., 2007), to execute alpine runoff models (Granell et al., 2010) or to simulate rainfall and runoff events in a watershed system (Goodall et al., 2011).

The problem we are addressing in this paper can be summarized as follows: SDIs intend, among other objectives, to contribute to the spatial enablement of societies. They can do so by providing the public with services and applications that give them a better knowledge about the territory where they live in. If these services and applications are properly designed and integrated, they can support geospatial business processes needed by different users with different objectives. There is much research on how to leverage Web services and SDI services to support geoprocessing final applications, as shown in the previous paragraphs. However, there is less research on SDI services that support both the implementation of different geospatial business processes and the provision of a graphical user interface (GUI) aimed at the general public (see (Granell et al., 2010) for a related example).

In this paper we propose a territorial analysis Web information system based on a number of SDI services. This system provides access to land cover and elevation data in Spain, besides some other auxiliary data layers. The SDI services can be included in geospatial business processes by researchers and other specialized users. A Web application for the general public is also

[3]Spatial Web services that follow OGC specifications.

provided.

The main advantage of SDI services is that they are created, deployed and maintained under a stable financial and legally mandated SDI, i.e. with a long-term compromise. It will be easier to maintain and improve applications built on top of a stable framework. These applications can also be developed in less time, because part of their functionality is provided by already existing services.

The rest of this paper is organized as follows. The next section describes a territorial analysis Web information system, with a focus on its architecture and on the SDI services that provide its main functionality. Section 3 shows two territorial analysis processes which can be implemented on the GUI provided by this information system, and a third one which is implemented in Python. These examples allow us to show some of the possibilities of the information system for both the general public, through the GUI, and for GIS professionals accessing directly to the SDI services. Section 4 includes a discussion on the results and some lessons learned. Finally, section 5 summarizes the main contributions and outlines some possible future work.

2. An SDI-Based Territorial Analysis Web Information System

The system presented in this work follows a Service-Oriented Architecture (SOA) (Erl, 2004), based on SDI services. The architecture of the system has been designed following the architectural style proposed by Béjar et al. (2009). This style provides guidelines to create views on the architecture of an SDI, in UML, based on the "Component & Connector" view type defined in the "Views and Beyond" software architecture methodology (Clements et al., 2003). An architectural view of the system following this architectural style is shown in figure 1.

As the architectural style is standards-agnostic, we have included a package with several OGC Web service types. These OGC Web service types specialize those defined in the style. The package also contains a new component type, `GazetteerApp`, which specialize `Application` and `GazetteerService`. A `GazetteerApp` provides a GUI to search for geographical names, but it also provides service interfaces for other applications.

The rest of the elements in figure 1 are rounded corner boxes, which are applications, squared corner boxes with underlined names which are service instances, and arrows with double tips which are the request/reply connectors between applications and services, and between chained services.

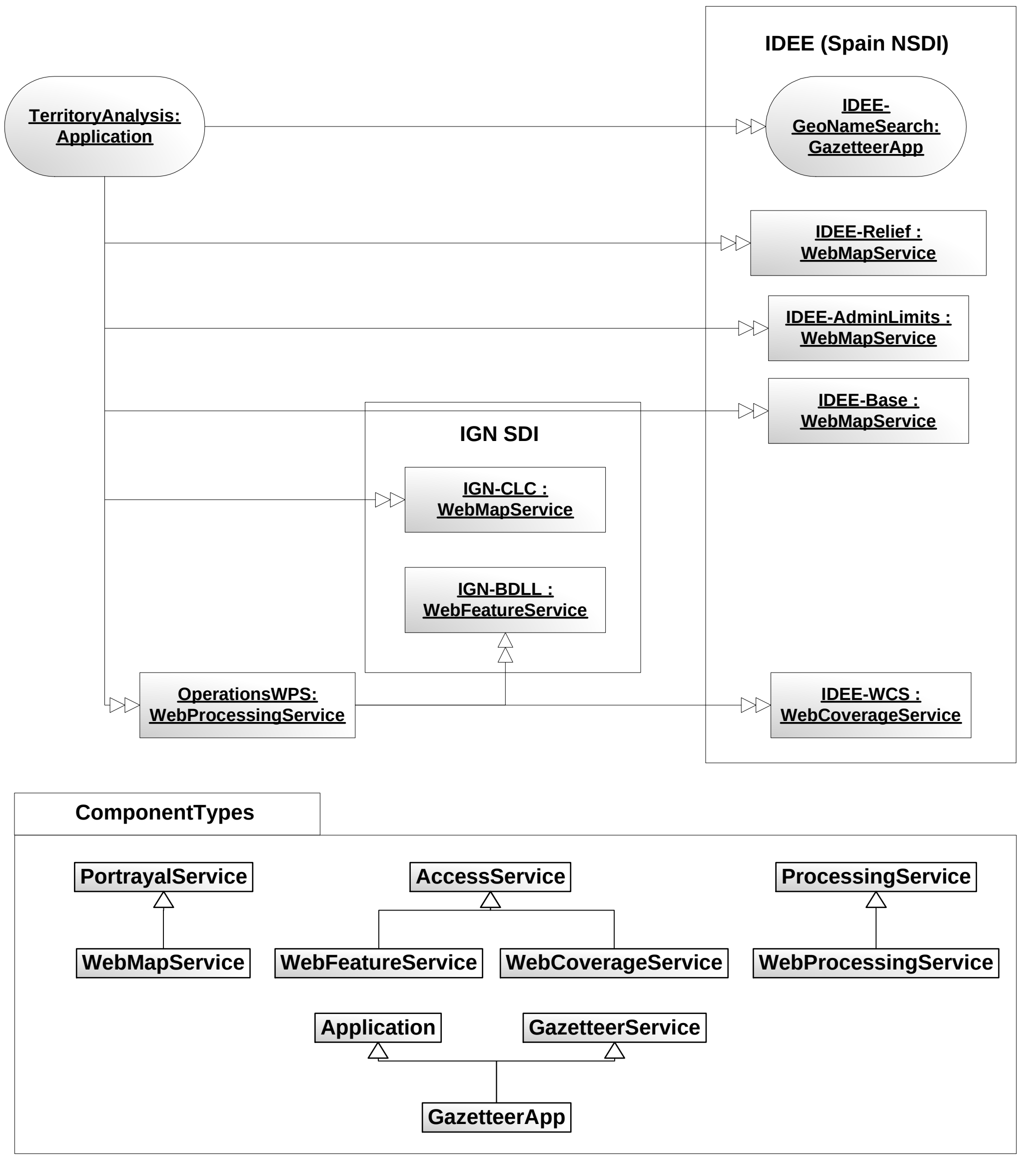

Figure 1: System architectural view

The architectural view shows the main Web application, `Territory Analysis`, connected to the Web services which provide most of its functionality and to another auxiliary application, `GeoNamesSearch`, which provides the geographic names search functionality and user interface. The Web services belonging to the Spain NSDI (*Infraestructura de Datos Espaciales de España*, IDEE) and to the Spain IGN (*Instituto Geográfico Nacional*, IGN) SDI, are shown in dashed boxes to highlight how our system reuses existing SDI services. The `OperationsWPS` Web processing service provides most of the specialized functionality of the system presented in this paper. The architectural view shown in the diagram is a simplification of the real system to facilitate the discussion in this work.

2.1. Web Services

As shown in figure 1, the Web information system uses several OGC Web Map Services, a Web Coverage Service (WCS) and a Web Feature Service (WFS). The WMSs include topographic maps, administrative areas, geographic names, relief maps and Corine Land Cover maps. The WCS serves relief raster data and the WFS provides administrative areas as polygons. All these services are part of existing SDIs (Spain National SDI and the Spain IGN SDI).

Besides these well-known service types, the main functionality of the system is included in the `OperationsWPS` Web processing service. Several of the operations provided by this WPS[4] support raster and vector data passed either *by reference*, i.e. the parameter is a request to a WCS or WFS, or *by value*, with the actual data as a parameter. Advantages and disadvantages of these two options, *by reference* and *by value*, in geographic service chains are discussed in Friis-Christensen et al. (2009). The WPS is implemented in Java with the Deegree framework[5], and its main geospatial functionality is implemented with GRASS[6] commands (Neteler and Mitasova, 2008), though additional work has been needed for parameter checking, data format transformations, executing WCS and WFS requests, and analyzing the results of

[4]The interested reader can obtain more details by querying the WPS itself, starting from its capabilities: `http://www.idee.es/WPS/services?SERVICE=WPS&REQUEST=GetCapabilities`.

[5]`http://www.deegree.org`

[6]Version WinGrass v6.3.0RC6

some of the GRASS commands (e.g. *r.mapcalc*). The main WPS operations are (GRASS commands in parenthesis):

- `getLineOfSight`: it calculates and returns a raster map with the visible area from a certain point given a DEM (*r.los*).
- `getProfile`: it calculates and returns a relief profile given a raster map and a series of points contained in it (*r.profile*).
- `rasterStatistics`: it returns height information about an area, defined as a vector polygon, given a DEM: maximum and minimum heights, their coordinates, average height and the raster map intersected with the vector polygon (*v.to.rast* and *r.mapcalc*).
- `simplifiedStatistics`: it returns height information about an area, defined as a vector polygon, given a DEM: maximum and minimum heights (*r.info*).
- `territoryAnalysisAreas`: it supports queries crossing a vector polygon, Corine land cover legend values and ranges of raster value (e.g. heights) (*r.mapcalc*, *v.to.rast* and *r.stats*).

Besides these operations, a number of GIS analysis functions, necessary to fulfill the requirements for the territorial analysis Web information system are also implemented by the WPS. These functions include different buffers, overlays and distance calculations, and they are also supported by GRASS commands.

2.2. Web Application

The territorial analysis Web application[7] provides the Spanish citizens with access to knowledge about their territory through a graphical user interface. This application, shown in figure 3, is the most visible part of the territory analysis information system described in this paper. Nevertheless, the information system also includes the data, the Web services and some functionalities not provided by the application GUI, i.e. provided directly through the Web services.

[7] `http://www.idee.es/clientesIGN/analisis_territorial/index.html?lang=EN`

The users start by establishing the territory of their interest, e.g. a municipality, and then navigate in an interactive map. The navigation is done through common GIS visualization tools, i.e. different panning and zooming options, and by searching geographic names. The application also offers other common tools, like distance and a surface measurements and map printing.

The territorial analysis options allow the users to select their specific area of interest (an administrative area or any polygon) and then to create different queries based on the existing Web services. This includes the possibility to generate and reuse intermediate results. These intermediate results appear as new layers on the map, and can be reused until the application is closed. The application does not allow to save or reuse the business processes themselves.

In the next section, the first two geospatial processes described are implemented in this Web application. This gives us an opportunity to show more details about how this application is used[8].

3. Territorial Analysis Business Processes

This section describes how the Web information system can be used to learn about the territory by chaining its Web services to implement business processes. The general public can do so by means of the graphical user interface provided by the Web application. Experts can integrate the offered Web services in their own processes with their own tools. The business processes are described at a conceptual level as UML activity diagrams.

3.1. Urban Growth Analysis in a Municipality

The growth of urban areas in Spain is a matter of interest, specially in the coast where this growth has been fast in the last decades. The first example is a business process that shows how a user can explore the urban growth in a given municipality. The business process is shown in figure 2. This process can be implemented using the GUI provided by the Web application and it is composed of these steps:

1. **Choose municipality**: a user launches the Web application and selects a municipality, for example Torremolinos in the south-east Mediterranean coast.

[8] A user manual is accessible from the application itself by clicking on the help button.

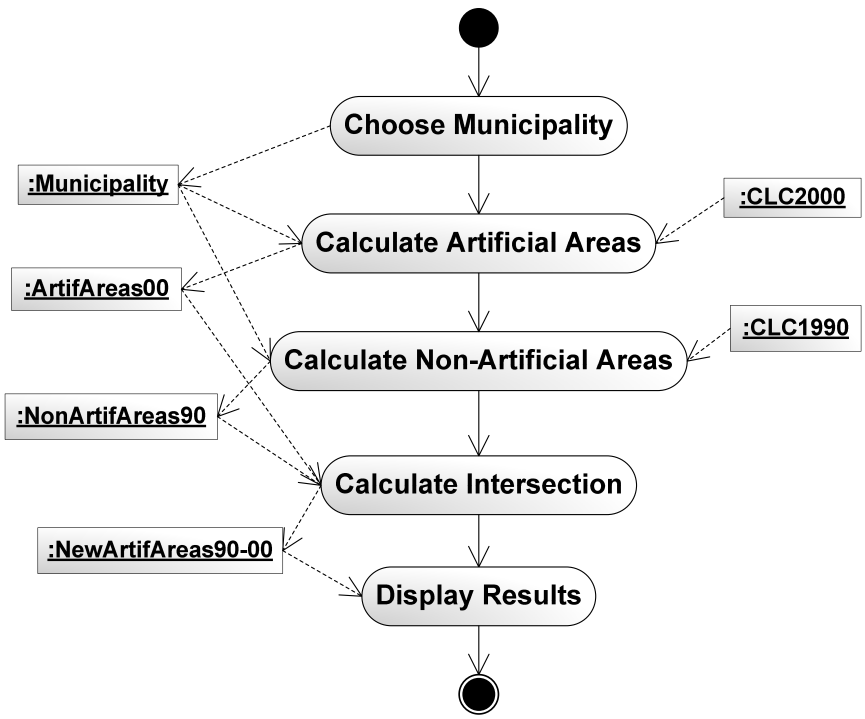

Figure 2: Business process: urban growth analysis in a municipality

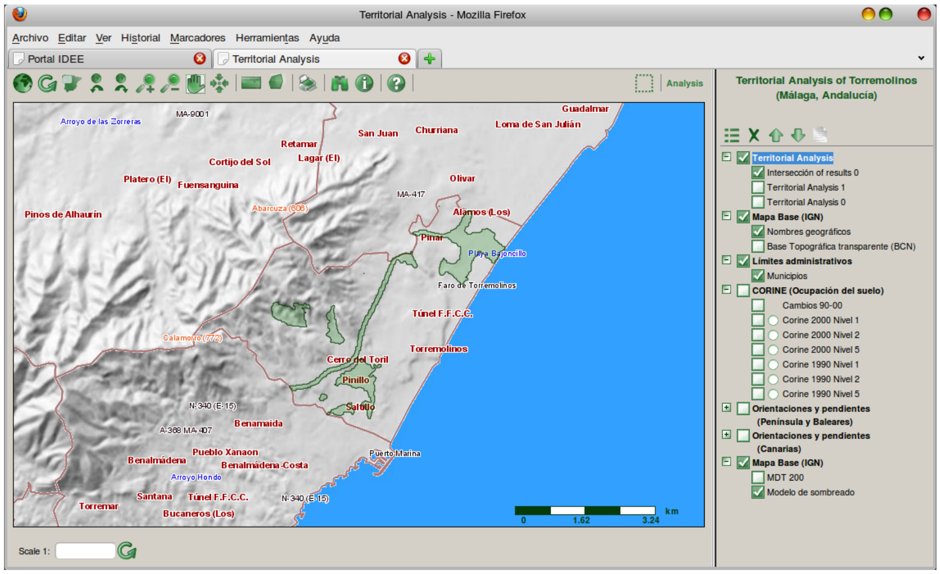

Figure 3: New urban areas in a municipality

2. **Calculate artificial areas**: the user chooses "Territorial Analysis", checks "Corine 2000, Level 1 (5 classes)" and "Artificial Surfaces" and clicks on "Show detailed information" and then on "View map". This generates an intermediate result ("Territorial Analysis 0") with the artificial surfaces in 2000 in Torremolinos.
3. **Calculate non-artificial areas**: the user repeats the previous step but this time checking "Corine 1990" and every Level 1 class *except for* "Artificial Surfaces". This generates another intermediate result ("Territorial Analysis 1") with those areas which were not artificial in 1990 in Torremolinos.
4. **Calculate intersection**: the user selects "Analysis -> Operations over analysis results", "Intersection of results" and the two intermediate results previously obtained.
5. **Show results**: the result is a new layer, in a translucent green color, which shows the areas which have been urbanized between the 1990 and 2000 (see figure 3).

This process can be easily tailored to show other "patterns of change" by choosing different Corine land cover classes in steps two and three. For

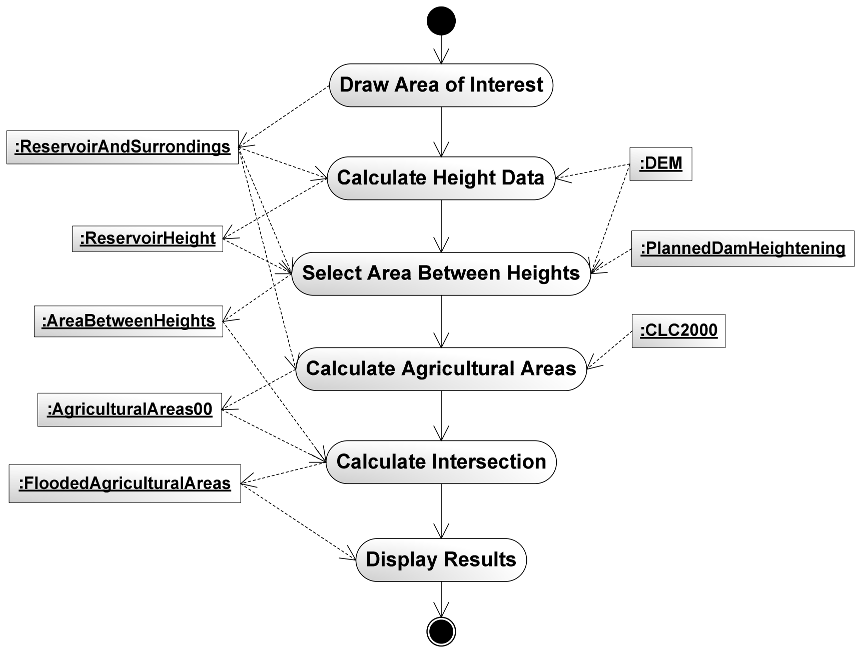

Figure 4: Business process: dam heightening effect on agricultural areas

instance, instead of choosing “artificial surfaces”, the users may focus on the growth or decrease in “agricultural areas” in a given municipality, or even how “agricultural surfaces” have evolved into “urban areas”.

3.2. Dam Heightening Effect on Agricultural Areas

The second example is a business process shown in figure 4, which allows a user to visualize some changes in the territory if a dam heightening project is carried out there. This process can also be implemented completely by using the Web application GUI and it is composed of these steps:

1. **Draw area of interest**: after locating the Yesa dam on the map, the user draws a boundary polygon around the reservoir (“Select query scope”, “By polygon”).
2. **Calculate height data**: the user “Query height data” to find out the height of the dam reservoir. The height is 485 meters.

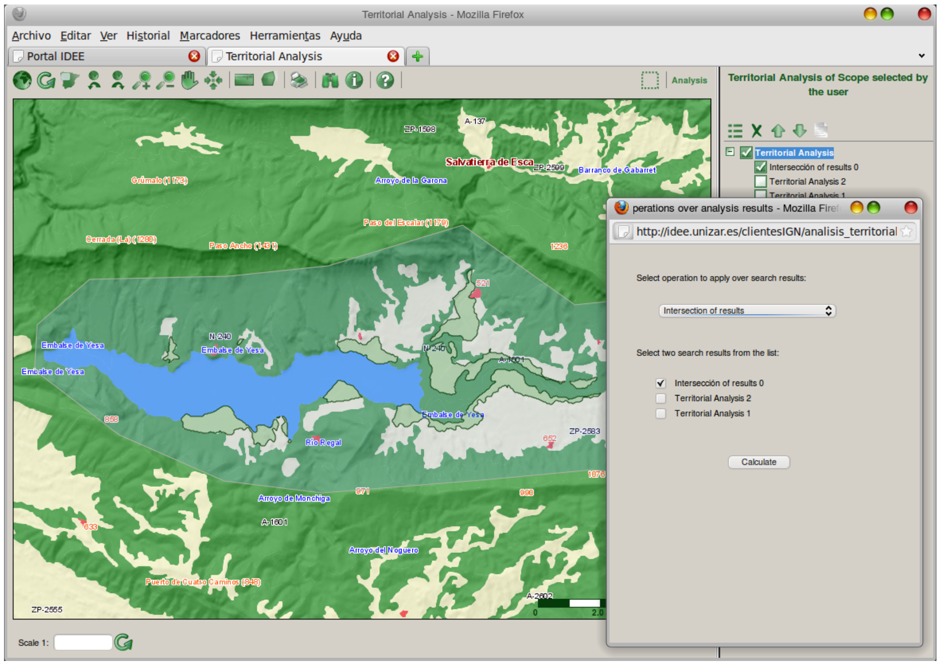

Figure 5: Agricultural areas to be flooded

3. **Select area between heights**: the user selects "Territorial Analysis", "Height between the interval" and inputs 484 meters and 510 meters, because there are plans to heighten the Yesa dam so the reservoir reaches that height. This generates an intermediate result with the surface that would be flooded by the new reservoir after the dam is heightened.
4. **Calculate agricultural areas**: the user makes a new "Territorial Analysis", but choosing "Corine Land Cover 2000, Level 1" and selecting only "Agricultural areas". This generates another intermediate with the agricultural areas in the boundary polygon.
5. **Calculate intersection**: the user selects "Analysis -> Operations over analysis results" an intersects the two intermediate results.
6. **Display results**: the resulting green, translucent polygons are the agricultural areas which will be flooded by the heightening of the Yesa dam (see figure 5).

The users may select other Corine land cover classes in step four to find out how different areas would be affected. The accuracy of the results of this process depends on the data provided by the services, and it is not clearly specified by them. This means that the results must be taken as approximate. For instance, currently it is not clear if the heightening would affect a road which surrounds the reservoir or not.

3.3. Territory Relief Report

The final example shows how geoscientists could incorporate the SDI Web services in their work. The example is a simple Web service business process implemented in Python that generates a report on the relief of an area around a given point of interest. Python has been chosen because it is a programming language widely used in scientific environments and with access to a good number of geospatial libraries (Westra, 2010).

This business process is shown in figure 6. Given a point of interest and a distance in meters, the program calculates a circular buffer around the point, calculates its boundary, requests elevation data in that boundary from the IDEE WCS, calls the `OperationsWPS` `rasterStatistics` operation to find out elevation information (maximum, minimum and average heights and location of the maximum and minimum heights), and then calls the `OperationsWPS` `getProfile` operation to create the relief profile of a straight line from the minimum height point to the maximum height point.

An implementation of this business process in Python is provided[9]. The implementation is just a simple test, and it should not be taken as an example of how to properly code a service chain involving SDI services in Python[10].

4. Discussion

The information system presented in this paper offers two possibilities to help users to implement geospatial business processes: the Web application and the SDI services. The Web application is aimed at the general public, while the services are composable pieces of geospatial functionality which can be reused by professional users.

[9] `https://gist.github.com/1250982`

[10] In particular, this code would benefit hugely from a library to encapsulate the requests to the OGC Web services instead of using parametrized XML strings.

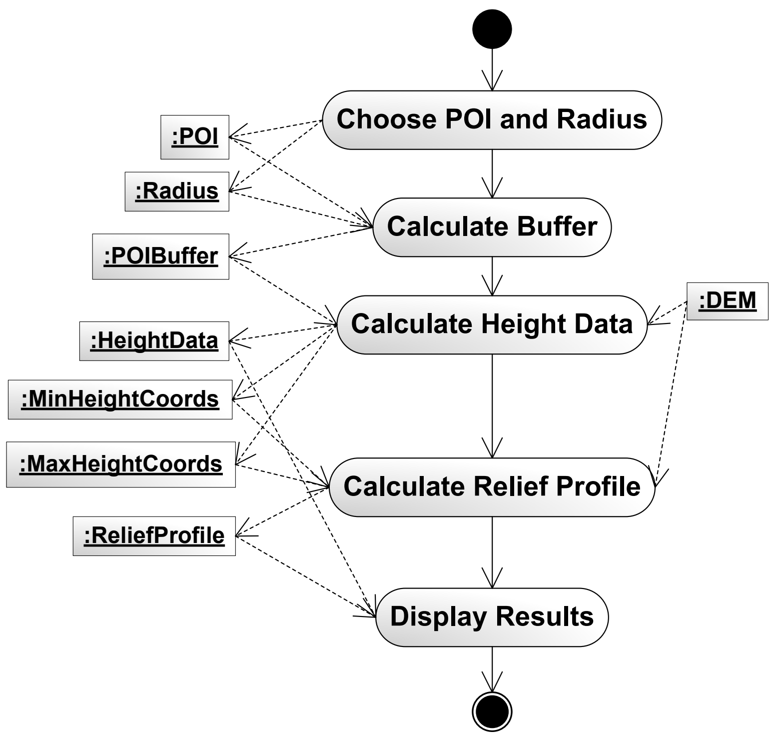

Figure 6: Business process: territory relief report

Regarding the Web application, the service-oriented approach has proven itself more flexible than traditional, monolithic strategies, as expected. Using already deployed SDI services (WMS, WFS, WCS) has allowed us to focus on the functionality required to provide the specialized operations to support territorial analysis business processes: the `OperationsWPS` processing service, and the GUI for the general public.

The Web application allows the general public to interactively explore their territory by composing different operations and queries. The application does not have a fixed set of supported business processes, neither requires the users to specify these business processes before running them. The focus is on simplicity and interactivity.

A different, but related, approach would be specifying business processes as workflows, and then implementing them using a workflow engine, such as Taverna (de Jesus et al., 2011). This approach requires modeling a set of business processes [11]. Although these models can be created with graphical tools, they are usually prepared by an expert in the problem domain. We see this approach a better solution when the business processes are known in advance, when they may be distributed for its reuse, or when it is important to make sure that they are followed in a complete, correct and efficient way, for instance in a professional environment.

The SDI services can be incorporated to business processes implemented as workflows, programs, as illustrated in section 3.3, or in desktop GIS applications. However, not every geospatial task makes sense as a service. For instance, it is not necessary to provide a polygon intersection algorithm as a Web service, when any desktop GIS provides one that is faster and more reliable than a Web service request. Professional users can make more profit from services that provide access to large datasets, specially if they are frequently updated, or from services which provide higher level, complex operations.

Building an application that depends on different Web services has the risk that if some of these services are poorly maintained, the application may fail. This risk is lower when the services are under the long-term umbrella of an SDI than when they depend on shorter-term projects. Other problems found with the use of SDI services include differences due to different versions

[11] For instance in BPMN (Business Process Model and Notation) `http://www.omg.org/spec/BPMN/2.0/`

or incomplete implementations of the standards, and the lack of detailed information about the quality of the data they use and about the algorithms they implement. Addressing these issues would be mainly a matter of resources, but in our experience it is difficult to get the resources necessary to improve something when stakeholders perceive it to be "already working".

5. Conclusions and Future Work

This paper has presented a territorial analysis Web information system which provides support to different geospatial business processes. This information system, established by the Spanish National SDI, gives access to land cover, topography, elevation data, and a number of geospatial operations through different SDI services.

The SDI services used by our information system come from two different SDIs, Spain SDI and IGN SDI. This is a good example of how different providers can be combined together to build new applications, thanks to their efforts to set up SDIs.

The SDI-based, service-oriented architecture of this information system has been described. Several examples of the geospatial processes that are supported have been presented. We have shown how these processes can be implemented by means of a Web application GUI. We have also discussed how geoscientists and other GIS professionals can include the services in their own business processes and workflows.

As future work, there are several aspects of this information system which can be improved. A second version would need to include more up-to-date data layers, to update the interfaces of the Web services to their latest versions, to support more geospatial operations and to improve the usability and responsiveness of the Web application, for instance by integrating tiled map services.

Another line of future work is the study of useful business processes which can be supported by the territorial analysis Web information system. These processes could then be implemented as new, parametrized, operations in the WPS, in order to facilitate integrating them in other applications. The implementation of the basic GIS operations in our system, necessary to provide the basic functionality of the Web application, would benefit from the adoption of one of the projects which are currently working to give access to

GRASS commands via WPS interfaces[12]. To facilitate the implementation of those new business processes, the use of workflow-based approaches and specialized languages, and their place and role in a Web information system as the one presented in this paper, should also be taken into consideration.

Acknowledgments

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[12] `http://grass.osgeo.org/wiki/WPS`

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