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INSPIRE Invoke Services

Survey on requirements, challenges and recent research findings supporting the development of the Invoke spatial data service specification

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Introduction

The aim of this study is to introduce the requirements and challenges for the development of INSPIRE Invoke services specifications. Invoke services provide a mean for invoking INSPIRE spatial data services, thus the dependencies between the Invoke and spatial data services are reflected in this study. In particular, a spatial data service interoperability arrangements study has recently started and here we anticipate some assumptions on spatial data service characteristics that will be used to define the context within which the Invoke development issues will be analyzed. Consequently this study will be validated, and eventually updated, against the spatial data service interoperability arrangements once it will be released.

The report is structured as follows. Section 1 concerns the analysis of the aspects characterizing spatial data services and the Invoke service, Section 2 illustrates the use cases emerging from the definitions and Section 3 is making a survey on the technologies suitable for the use cases and the recent findings in the research field. Finally, Section 4 is presenting an initial contribute towards the Invoke service specifications

Spatial data services

The definition of spatial data services included in the INSPIRE directive [1] is the following*: 'spatial data services' means the operations which may be performed*, *by invoking a computer application, on the spatial data contained in spatial data sets or on the related metadata*.

It is worth noting that on the one hand the definition does not mention the way the spatial data service can be accessed, therefore it could be a spatial data service running on a stand alone computer, and on the other hand the spatial datasets and services are to be made available through the Internet by means of INSPIRE Network Services that must be public and accessible via Internet. In the specific case of spatial data services the Network service to be used is the INSPIRE Invoke service.

The taxonomy for spatial data services types we will consider is defined in the Commission Regulation (EC) No 1205/2008 of 3 December 2008 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards metadata, for simplicity reported in Section 7.

In order to make the discovery and invocation of such spatial data services possible, interoperability technical arrangements are necessary. This need is expressed in Article 7(1), asking for laying down technical arrangements for spatial data services. Since the related implementing rules are not yet available, this study anticipates the fundamental dimensions that will be used for investigating the challenges in developing Invoke services.

Our findings will be based on the spatial data service definition and on the taxonomy for spatial data services. Of course the input may be not enough for supporting all the potentially useful use cases, hence it has to be considered an initial set of dimensions eventually subject to extensions and modifications once the interoperability arrangements implementing rules for spatial data services will be defined.

The fundamental dimensions characterizing the spatial data services are the ones defined in the OASIS *Reference Model for Service Oriented Architecture* [3] to which we added the scope dimension:

- **Actor**: description of the actor using the spatial data service. Spatial data service can be designed for dealing with human users or applications. In particular, "human category 100" of the spatial data service taxonomy represents those services explicitly devoted to interact with human users. It is worth to note that the actor is not always specified and in some cases it could be either human or application. This ambiguity is due to the fact that the taxonomy uses different dimensions to categorize and describe services: it always includes the functionality while the actor using it is not always mentioned as in the case of category 300. However, for the sake of spatial data services integration, this aspect will necessarily have to be described in the spatial data service interoperability arrangements.

- **Interface**: the way the actor can communicate for requesting and getting the result of the service. If the actor is a human user it could be web application interfaces, or else if the actor is an application it could be a service interface that applications can use for invoking the various operations.
- **Reachability (Communication means)**: service interfaces must be reachable. The directive does not indicate or suggest the way and the mean spatial data services should be accessed; it could be publicly accessible through the network as well as accessible via authorized staff (that for instance might have the spatial data service in its local network). The communication means for interacting with the spatial data services are therefore spanning on very heterogeneous types like HTTP or E-mail/FAX.
- **Scope (range of operation)**: since spatial data service do not necessarily have to be publicly accessible over the Internet we also introduce the notion of scope which indicates within which spatial extent or computer network the spatial data service can be reached. Note that the way it is expressed may depend on the communication mean: if it is a Internet protocol (HTTP, SMTP, …) it could be defined using the network scope (e.g. Internet, local network) while in other cases, like for the FAX, it could be necessary to express the reachability scope as a spatial extent (e.g. requests accepted only from national FAX, or nationals Internet domains).
- **One-way interaction modality**: the way actors and spatial data services interact each other. The usual modalities are synchronous and asynchronous.

It is worth to remind that the spatial data services access might be protected by authentication mechanisms or subject to charges. This aspect, although very relevant, for the implementation of the infrastructure is not currently considered crucial for the aims this study is pursuing. Depending on the evolution of the Invoke service and on the outcome of the spatial data services study this aspect may be introduced in the following version of this report.

Example (view client). The French cadastral map consultation service, available at http://www.cadastre.gouv.fr/scpc/changeLangue.do?lang=en&cty=EN is an example of a spatial data service linked to a spatial data set related to the Annex I "cadastral parcels" spatial data theme and as such it shall be described with INSPIRE spatial data service metadata. In particular the spatial data service type would be '102 Geographic viewer (humanGeographicViewer)'. The French cadastral map consultation service is designed for human users and it is reachable through HTTP t over Internet. The interaction modality is synchronous for both request and response.

Example (coordinate transformation). The service type '402 Coordinate transformation service' could be registered in INSPIRE for offering a spatial data service able to transform coordinates from a coordinate reference system to another. Note that functionality wise this service might fall within the Transformation service definition (note however that it is not necessarily to be available over the Internet) or it might be a tool used in a user transparent way by Download or View services for releasing harmonized data. In the latter case its scope could be the local network in which also the network services are running and able to access it. Most probably it would be designed for being used by specific components, with an interface not necessarily standard reachable with HTTP. This means that in order to expose it in the INSPIRE infrastructure it should be made publicly accessible via the Invoke service. The interaction modality of this service type could presumably be synchronous even though long transformation processing may need asynchronous interactions.

Thanks to these examples it emerges that the Invoke service, as responsible for offering on the Internet a mean for invoking spatial data services, will have to take into account a number of diverse cases whose main dimensions are actor, reachability, scope and interaction modality.

Invoke service

The INSPIRE directive defines the scope and the role of Invoke services via the following sentences:

Article 4(3): *This Directive shall also cover the spatial data services relating to the data contained in the spatial data sets referred to in paragraph 1.*
Article 11(e):

> *services allowing spatial data services to be invoked.*
>
> *Those services shall take into account relevant user requirements and shall be easy to use, available to the public and accessible via the Internet or any other appropriate means of telecommunication.*

Article 14(4): *In addition, where public authorities levy charges for invoke spatial data services, Member States shall ensure that e-commerce services (including rights management services) are available.*

This means that the Invoke service has to be accessible via Internet and offer a mean to invoke the linked spatial data services.
A previous work [2] made an effort in detailing the legal text definition as follows:
Proposed Interpretation: For spatial data services performing a mathematical calculation and available on the Internet, the "invoke spatial Service" service will enable a user to run it without requiring the availability of a GIS.
Proposed Assumptions: Only the generic description of the spatial data service algorithms and specific parameters are in the scope of the specifications and Implementing Rules for the "Invoke Spatial Data Services" service.

Here we will focus on the activities the Invoke shall support in order to allow clients invoking spatial data services; the other functionalities facilitating the discovery and the use of Invoke services will be discussed in Section 0 (the complete list of Invoke service operations is proposed in Section 0). The technical solutions for implementing the Invoke service depending on the characteristics of the linked spatial data service will be discussed in Section 0 and 0.

In [3] the service invocation is described in terms of consequences it implies:

> "The consequence of invoking a service is a realization of one or more real world effects (see Section 3.2.3). These effects may include:
> 1. information returned in response to a request for that information,
> 2. a change to the shared state of defined entities, or
> 3. some combination of (1) and (2).
>
> Note, the service consumer in (1) does not typically know how the information is generated, e.g. whether it is extracted from a database or generated dynamically; in (2), it does not typically know how the state change is effected."

This description highlights the importance of distinguishing the invocation, execution and response phases where the last two are consequences of the invocation. This separation is particularly important due to the vast spectrum of spatial data service characteristics as remarked also in the example aforementioned.
Accordingly with this definition, the sequence of actions for using a service is:

1. service invocation, which triggers the service execution and includes all the necessary parameters,
2. spatial data service execution, which is out of the control of the invoker, and
3. result consumption which could be performed either by the invoker or by a third party.

Depending on the spatial data service characteristics (e.g. partially or totally off-line) the Invoke may or not be in condition to directly reach and communicate with the spatial data service as well as get the result of its execution. However, the Invoke service has to offer the mean or the information enabling the handling of all the three steps without, as reported also in [2], requiring a GIS.

The examples of spatial data services given in the previous section will be used here for discussing how the Invoke service could implement spatial data service invocation and all the related activities.

Example (Invoke view client). The French cadastral map consultation service is designed for human users, reachable via HTTP as common web applications, therefore the invocation of spatial data service could be submitted directly to the geographic viewer itself. However, the Invoke service could result useful for documenting the spatial data service including, for instance, all the information relevant for the evaluation and use of the spatial data service.

Example (Invoke coordinate transformation). The Coordinate transformation service is reachable via HTTP from the local network. The responsible for the spatial data service should then decide how to expose the service and precisely how the Invoke interacts with the service. One possible solution is that the rights for accessing the spatial data service interface are given to the Invoke by deploying it, for instance, in the same local network. If this solution is not applicable, one alternative is to create a sort of proxy which receives all the requests submitted to the spatial data service and invokes subsequently the service. The spatial data service reachability, over the whole Internet, is in this case guaranteed by email or other means reaching the proxy. Finally, one important aspect pertains the invoke operation interface. One of the biggest challenges in this sense will be define common rules, or best practices, for creating the interface out of the spatial data service characteristics; the invoke operation could use a standard interface which is then, behind the scenes, used to create a valid spatial data service request message according to its interface.

Use cases

The use cases listed in Figure 1 relate to the requirements expressed in the directive, which are the ones where the actor is the Invoke Service user, and the requirements regarding the creation and description of the Invoke service. The latter category of use cases will help in identifying the dependencies with spatial data service interoperability arrangements: any proposals should be reflected in, or validated against, the Interoperability arrangements Implementing Rules for spatial data services.

Invoke specific use cases

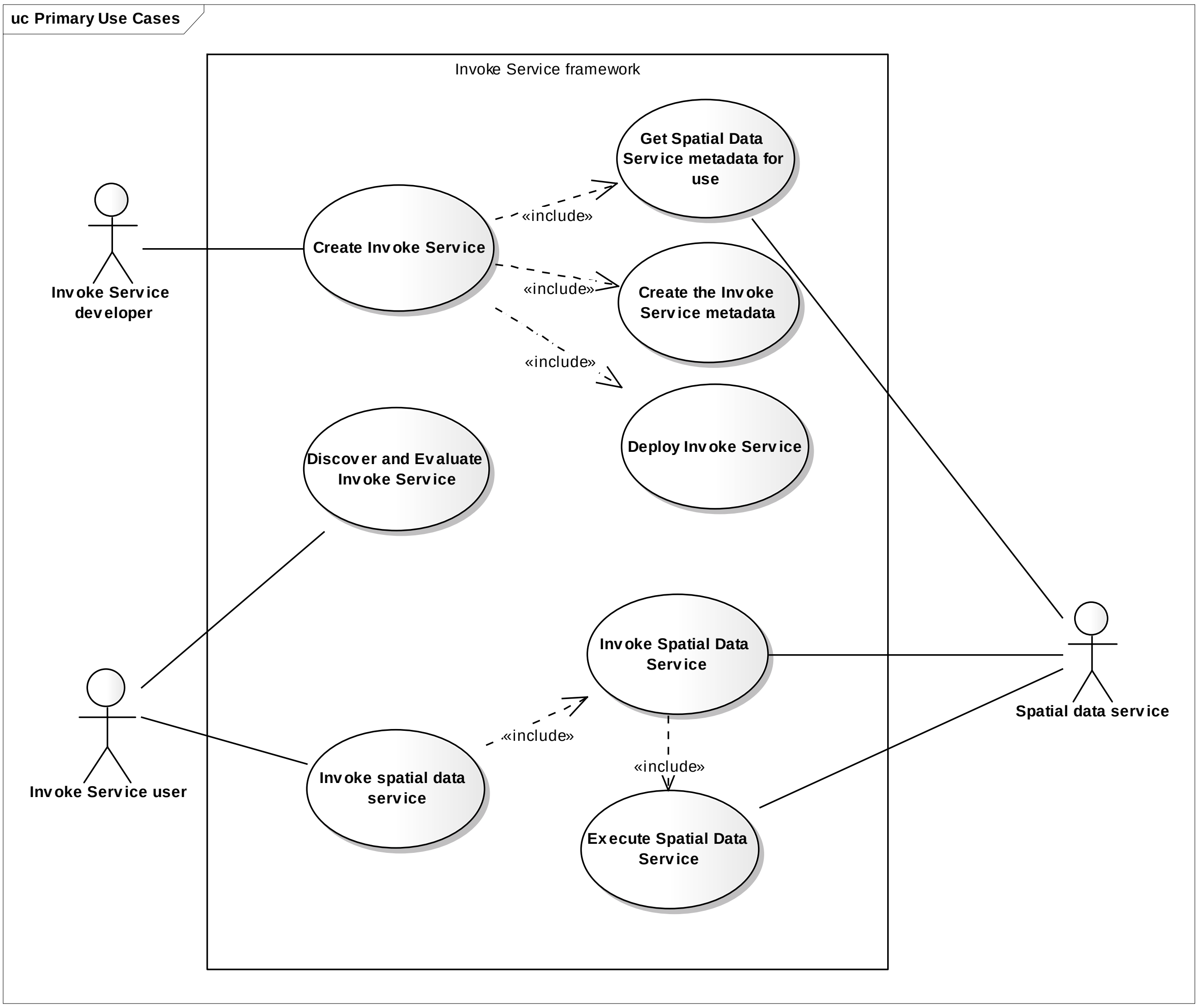

Figure 1 INSPIRE Invoke Service use cases

Discover and evaluate Invoke service

Use case: discover Invoke Service
Primary actor: Invoke Service user
Description: the user discover a spatial data service, or a dataset and in a second step the associated spatial data service, and out of it wants to derive the (if any) Invoke services supplying that specific spatial data service.
Requirements: spatial data and spatial data services must be described through INSPIRE compliant metadata [4].

Use case: evaluate Invoke Service
Primary actor: Invoke Service user
Description: in order to evaluate and eventually use the Invoke Service the user assesses its fitness for purpose by evaluating its metadata.
Requirements: metadata for the evaluation of the Invoke service must be available and accessible.

Invoke spatial data service

Use case: execute Invoke Service
Primary actor: Invoke Service user

Description: the user, potentially with the help of an application, triggers the Invoke spatial data service operation by passing all the parameters required by the linked spatial data service as declared in its metadata. In order to get the result of spatial data services additional interactions and services may be necessary. When possible however the result shall be directly returned by the Invoke service.
Requirements: the Invoke service operation is available and it supplies access to the required Spatial Data Service. The input parameters (e.g. datasets or other resources) are passed in the format supported by the Invoke service.

Invoke service related use cases

Create Invoke service

Primary actor: Invoke Service developer
Description: The developer, given a spatial data service, implements the corresponding Invoke service operations. These includes at least the invoke operation, and the creation of Invoke spatial data service metadata operation adequately documenting the Invoke operations interface (parameters, interaction modality, …).
Requirements: all the necessary information about the spatial data service must be made available as required for the development of the Invoke and for its description (metadata).

Combine multiple service invocations

Article 11(3): "The transformation services referred to in point (d) of paragraph 1 shall be combined with the other services referred to in that paragraph in such a way as to enable all those services to be operated in conformity with the implementing rules provided for in Article 7(1)."
This article essentially points out that Transformation service is devoted to make spatial datasets compliant with interoperability arrangements for spatial datasets, and that it might potentially be combined with the other Network services in order to serve, through these services, spatial datasets compliant with article 7(1)., In this scenario, MS could decide to use the Invoke as solution for combining several network services: if a Download service is offering spatial datasets that do not obey at the interoperability arrangements then the gap might be closed by implementing a Invoke service sequentially invoking the Download and Transformation services offering correspondingly spatial datasets (not yet entirely compliant) and harmonization processing operations. This use case is particularly linked with workflows and in Section 0 the available technologies will be described.

State of the art

Figure 2 tracks the dependencies between spatial data service, Invoke service and its client. Although the Invoke service interface is independent of implementation details, the actions for invoking and getting the result of spatial data services may vary depending on some characteristics of the spatial data service itself. In certain cases, for instance when the spatial data service is reachable only via off-line means (e.g. FAX), the Invoke service client might have to deal with the spatial data service even though its initial reference will remain the Invoke service. Another similar example is the geographic viewer in Section 0 where the user directly deals with the spatial data service.
Another interesting implementation detail is about
The interactions coloured in blue represent an interesting implementation detail between Invoke and Spatial data service. If actor implementations exist (for example if a client application equipped with API has been implemented and made available) the Invoke implementation could use such implementations for invoking the spatial data service.

From the diagram it also emerges that the only characteristic to be merely addressed during the implementation and not affecting the Invoke interface and its client is the way to interact and pass parameters to the spatial data service.

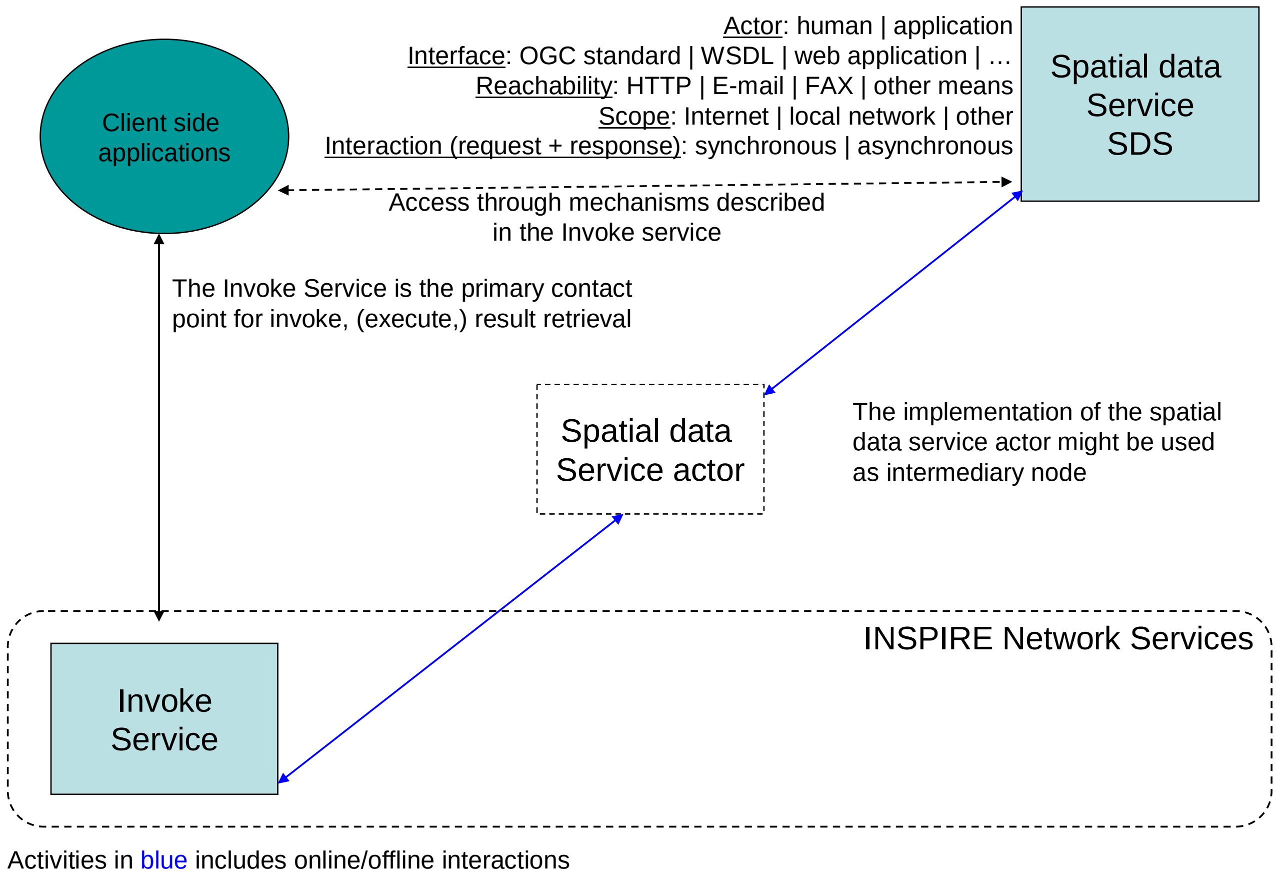

Figure 2 Interdependencies among Invoke, spatial data service and actor

The following subsections present the solutions deemed mature or applicable for facing the identified use cases in the scope of spatial data service and Invoke definitions.

Web service contracts

A service contract basically consists of defining the service, like the modalities through which client and service can interact, what it does offer, which quality of service are guaranteed. Such contract can be used to drive the development of clients as well as services and this approach is called model driven. One significant part of the service contract concerns the service interface. Usually it contains the endpoint at which the interface is available, the parameters and the corresponding supported encoding and communication means. One W3C standard language devoted to express such a contract is the Web Service Description Language (WSDL) [5]. In the spatial domain, similar information is contained in the capabilities document each standard OGC service offers.

WSDL has specific section for describing the operations, the parameters, the endpoint on the network reaching the service and finally the interaction mean and protocols that has to be used to transmit requests to the service. Although WSDL covers a number of communication means (e.g. HTTP GET, HTTP POST) called service bindings, it is usually coupled with the SOAP (Simple Object Access Protocol) binding.

A number of tools are offering a mean for automatically generating client and service skeletons faithfully following a given WSDL contract. For example Apache Axis (http://ws.apache.org/axis/) is a tool generating the Java code for properly handling service and client development and the defined

message types. Axis only supports the implementation of SOAP based services.
The Apache Web Service Interoperability Framework (WSIF, http://ws.apache.org/wsif/) is instead fully exploiting the WSDL. In particular it generates an API for invoking the service which is independent of the underlying service binding expressed in the by WSDL: services exposing the same WSDL contract except for the used binding (SOAP, HTTP POST, …) can be programmed in the same way. In certain circumstances the use of a service can require more than one single interaction, in these cases the usage of the abstract part of BPEL (see Workflow section) can be used for describing the expected service and client behaviour.

Due to the benefits of such a standard contract description language and to what stated in [6] a study aiming at defining an INSPIRE SOAP framework has been launched in 2008. The outcome of that study consists of a SOAP framework document [7] describing the common rules, and the set of solutions recommended for implementing INSPIRE Network services with SOAP binding. Following such guidelines another document [8] describes the WSDL and the SOAP messages for the INSPIRE Discovery and View service interfaces.
OGC has also adopted rules for generating the WSDL and the SOAP binding in OWS-Common specification version 1.2. In terms of expressive power it is worth to point out that the capabilities document used to describe OGC services can be used as well as a mean to describe the contract. The WSDL in the OGC proposed solution is used for describing the SOAP binding. At the best of our knowledge currently there is no tool able to automatically generate service and client applications out of the capabilities document.

Another relevant part of service contract regards the quality of service; aspects such as response time, availability and other criteria are relevant in the INSPIRE infrastructure and they are for instance defined in the regulation about Network services. This aspect, called service level agreement (SLA), can be expressed by using WSLA Language Specification.
Another interesting proposal is WS-Agreement. The goal of WS-Agreement is to standardize the terminology, concepts, overall agreement structure with types of agreement terms, agreement template with creation constraints and a set of port types and operations for creation, expiration and monitoring of agreements, including WSDL needed to express the message exchanges and resources needed to express the state.

As we will show in the following sections, WSDL or capabilities are not expressive enough for properly describing and using the spatial data service.

Other invocation means

Even though the message passing is the *de facto* standard in which web services interact each other, other means could potentially be used and in this section we will briefly introduce some of them. This alternatives would not imply that all the INSPIRE services shall interact in this way, but they might result useful in the specific case of enabling the collaboration between spatial data services and Invoke services.
One alternative that could be used to decouple communication means, availability of services from the service usage is the coordination of services via tuple spaces (e.g. IBM Tspace, Sun Jini Javaspaces). In [9] the design and the implementation of a higher level interaction model for Web Services that follows the tradition of data-driven coordination model is presented. Web Services do not coordinate via direct service invocation, but their interaction is mediated by a coordination space where shared data are stored and retrieved. An interesting usage of such a model is the implementation of a mechanism [10] for balancing the workload distribution among equivalent resources. At run-time, depending on the equivalent resources available, the mechanism determines which of the available services has to undertake the request.
As part of research studies also agents systems have been used as well to investigate how to enable

invocation of Web services [11]. Finally, also grid system solutions may be suitable for supporting the invocation of spatial data services. For a mature assessment of the suitability of these solutions further investigation work is required.

Synchronous and asynchronous invocations

The asynchronous invocations basically decouple the phases in which the service execution is triggered and the result is retrieved. They can be implemented in different ways: the crucial point is the way the availability of the result is checked that can be by using a push or a pull mechanism. The pull (polling) method essentially consists of regularly checking, from the client side (in general externally to the invoked service) the availability of the result. In order to properly identify the right execution session the invocation interactions normally returns an unique session identifier, alternatively correlation sets (supported in BPEL) can be used. Once the result is ready the client can get it either via invoking a specific operation or by downloading the content of a specific URL. The push mechanism is implemented in the OGC WPS specification and it provides a mean to get the result on URLs.

The push (callback) solution delegates instead the invoked service (or another component on behalf of it) to inform the invoker about the availability of the result. Once this notification is performed the client can get the result as in the pull mechanism. The push can be implemented, for instance, by using WS-Notification and WS-Addressing, publish-subscribe or tuple space based mechanisms.

Although in both approaches it would be possible to join event notification and result, i.e. informing about the availability and passing it in the same interaction, this is normally a good practice. In particular, the result retrieval could be performed different times or by another service using it (see [18] for common data flow patterns).

Workflows

Although workflow scope is slightly beyond the Invoke service functionalities (it is explicitly mentioned only in the “Combine multiple service invocations” use case), the core issues workflows address are suitable for facing the Invoke implementation, especially for identifying the needs and solutions for the ‘Invoke spatial data service’ and the ‘Create Invoke service’ use cases. Workflow languages have been used in the context of Service Oriented Architectures (SOA) for enabling the creation of new functionalities out of the ones offered by existing services. Precisely workflow languages are used as the mean for describing the actions (e.g. service invocations, events to be handled, internal computation) and their dependencies (e.g. sequential, parallel, conditional) that must be performed in order to achieve the required functionality.

Two different workflow design methodologies are currently available. The first approach, referred to as Web services *orchestration* and implemented by different technologies like BPEL [12], XLANG [13] and WSFL [14], defines the workflow using the viewpoint of a central coordinator (the orchestrator) coordinating available services by taking the responsibility of invoking and combining the single activities. This approach makes it possible the execution of such workflow specification (hence the name of executable workflow specifications) thanks to workflow execution engines exposing the workflow execution itself as a new single service (usually called workflow service). However, the BPEL can be also left in its abstract form which is independent of some details like the endpoints and bindings used by involved services. The abstract BPEL is normally used either for describing workflows that can in a second stage be executed (prior to having completed the binding with the necessary services) or for describing the behaviour of the service itself (potentially useful in service contracts).

The second workflow design approach is based on abstract workflow specification and is implemented by WS-CDL [15] and BPMN [16]. It defines complex tasks in a more abstract way and in particular it does not necessarily require the existence of a central coordinator. The used abstraction level is usually platform independent in the sense that used tasks may also omit an explicit reference to the associated

services; this mapping can therefore be done later during the implementation. This sort of abstraction also makes the descriptions more comprehensible also for users without programming skills; this is not always the case for executable workflow specifications where a number of technical details (message creation, manipulation, ..) necessary for the execution of the workflow have to be programmed. Another difference due to the fact that a central coordinator is not mandatory is the way to express interdependencies between actions, precisely the synchronization activities between distributed services preserving the right order of interactions may not be programmed at this level.
In this study we will focus on executable workflows and on the most credited and used solution which is BPEL. BPEL is requiring the WSDL for all the services involved in the workflow and for the workflow service itself that will be executed and exposed through a workflow engine. More precisely this means that the service interfaces that a BPEL engine can expose and invoke are the ones that can be expressed with WSDL and its supported communication means (e.g. HTTP GET, POST, SMTP), this capacity of supporting different bindings is exploited for instance in SSE (see next section).
BPEL provides all the constructs for programming applications, from the basic activities like service invocation, error handling, and conditional statements to the constructs for the sequential or parallel composition of activities. It also includes operations for manipulating messages whose structure is automatically derived from the WSDL of used services. Such manipulation is necessary in order to allow the extraction and the reusage of (part of) messages in other service invocations.
A number of tools assisting in the design of BPEL workflows and in their execution are available. The most used tools for workflow design are Oracle BPA Suite, ActiveBPEL designer and Intalio while for the execution are Oracle SOA Suite, ActiveBPEL engine and Apache ODE.

Next section will describe actual cases of application of such technologies for enabling interoperability in geospatial services infrastructures. Although these solutions proved that it works currently there is neither a standard nor a common agreement on how to support service invocation and composition.

Platforms based on workflow languages

The Service Support Environment (SSE) platform[1] was born in October 2004, from an ESA General Support Technology Programme (GSTP) project - know as MASS / Multiple Application Support Service System. Due to the interest it has generated, SSE has become an operational system since 2005, known as the “Service Support Environment”.
Among the other functionalities it supports service designers in creating new services by integrating a wide range of heterogeneous EO and Geospatial information services, including product catalogues, innovate the EO field by sharing ideas and skills with its best professionals. This goal is achieved by offering a workflow engine, precisely a BPEL engine, that executes the service invocations and expose this functionality as services.
Thanks to BPEL and its engine in this platform it is possible for instance expose a service offering access to services running remotely that, for some reasons, are not directly or easily usable. For instance, it is possible to program a simple BPEL workflow which invokes a non standard service and exposes the workflow service by using a standardized interface; in this case the workflow service is acting as a wrapper which basically rephrases the requests and the responses of the services behind. One additional advantage is about adding or modifying the service binding; with a BPEL engine it is possible to support any service binding provided that it is supported by WSDL. In this way it could be implemented, for example, a service with SOAP binding and related security protocols by relying behind on a service originally designed for supporting the HTTP GET binding.

The ORCHESTRA FP6 project[2] [17] had a pilot on Pan-European Assessment of Natural Hazards whose primary aim was to demonstrate the implementation feasibility of distributed data retrieval, data harmonization and processing coordinated by workflow engines. The most important lessons learned

1 http://services.eoportal.org
2 http://www.eu-orchestra.org

were about the issues related with the data passing by reference and by value, and the interface the workflow service has to use. The former aspects significantly affect performances and scalability of the application, for the reader interested in all the aspects and solutions we suggest to refer at [18]. The latter aspect instead has not yet been entirely solved, so far there is no standard way to express the interface of a workflow service; at the state of the art the most adequate solution is probably the usage of OGC WPS [19] interface which is substantially a meta-interface allowing to encode any variety of service operation interfaces. All the details on the pilot implementation are reported in [21].

Use cases implementation feasibility study

In this section the feasibility of implementing the most relevant use cases is evaluated. In particular the aforementioned technologies will be used to assess the maturity of solutions and the issues that are still unresolved.

Discover and evaluate Invoke service

The INSPIRE metadata regulation plays a crucial role on the implementation feasibility of such use case.
Concerning the evaluation of Invoke service the information about the linked spatial data service shall be provided by the Invoke service itself (see in next section the get service metadata operation) while the discovery of the Invoke driven by the spatial data service that the user is willing to invoke may need more information than what is foreseen for the spatial data service metadata elements.

Invoke spatial data service

In the case the service is a user web application the definition "*services allowing spatial data services to be invoked*" could be implemented simply by redirecting the user to the application. In the case instead the service interface is designed for applications the Invoke operation shall take at least the responsibility of invoking the spatial data service and handling the result in a way that the user can, directly from the spatial data service or through the Invoke operation, access it.
In both cases the sequence of steps necessary for invoking spatial data services and their results can be complex enough for justifying the usage of abstract workflow notations that could facilitate the implementation of the behaviour for successfully completing the invocation. More precisely, high level notations could complement the service contract by expressing the behavioural rules to be implemented for using the spatial data services.

Create Invoke service

It is worth noting that even though the directive does not explicitly describe this use case for the Invoke, Article 12 of the directive (link third parties services) has implications on the Invoke that are mostly reflected in the problem of generating the invoke spatial data service operation.

The technologies mentioned before are mainly supporting this use case. In particular, the WSDL and more precisely the information it describes are always necessary for guaranteeing that a service can be properly invoked. In the specific case of spatial data service this information must be complemented with all the details about the spatial data services characteristics identified in Section 0.
Table 1 Spatial data service description elements summarizes how to use the spatial data service characteristics for deriving the corresponding Invoke operation and which information can be expressed with WSDL or similar documents such as the OGC capabilities document.

Table 1 Spatial data service description elements

Element	Description	Usage	How to express
Actor	Human being or application and if necessary additional details (e.g. required expertise, qualification, user login)	It determines whether the invoke operation has to redirect the user directly to the spatial data service or play as mediator between the user and the spatial data service.	No standard solution.
Interface	The interface can be for human users or designed for applications.	The interface of the Invoke operation will be defined (refined if a meta-interface is already available) out of the spatial data service interface.	The details could be, in the case of actor = application, the ones appearing in the WSDL (mandatory if BPEL workflows are required) or in the capabilities document.
Reachability	The supported communication mean (HTTP, FAX, E-mail, mail, …)	It determines how the Invoke sends the invocation request to the spatial data services and, to some extent, also how the result can be passed to the user.	Partially addressed in WSDL and OGC capabilities.
Scope	The interface reachability scope (Internet, local network, geographical boundaries, …)	It has implications on where the invoke has to be deployed (necessarily inside that scope)	No standard solution.
Interaction modality	Defines for the request and the response the interaction modality (sync/async)	It determines how the availability of the Invoke operation result is notified and how to get the result	Partially addressed in WSDL

The case in which the spatial data service is available over the Internet, described by a WSDL or via a capabilities document (if this is an OGC compliant service) has the lowest difficulty level in implementing the invoke operation and it could be further simplified thanks to tools like Axis or WSIF. It is also worth point out that some communications means like FAX and E-mail could be offered by some services on the network and therefore spatial data services using these means could be invoked by relying on these intermediary services playing as mediators.

Open issues

This section reports some of the issues that still need to be addressed or that depend on the development of related technical components.

- What are the implications of article 12 (link third parties services) for the Invoke? In this study such article is interpreted as the capacity of generating a new Invoke service once a third party is willing to provide and register in the INSPIRE infrastructure a spatial data service compliant with the interoperability arrangements.
- Point (17): "*Those network services should make it possible to … and to invoke spatial data and e-commerce services*". The current spatial data service taxonomy does not cover E-commerce services which could also be accessible via Invoke services. If this is the case, some aspects like the spatial data service taxonomy might need an extension..
- The Resource locator attribute of a spatial data set's metadata could be filled with a link to a relevant spatial data service and not to the Invoke service This may complicate the discovery when the user starts with the dataset; the infrastructure should allow for discovering the relevant spatial data service(s) and subsequently, the corresponding invoke service.
- The dependency of the quality of service requirements that might be requested for the Invoke on the linked (decoupled) spatial data service may lead to ensuring a minimum level of service from the spatial data service as part of the interoperability arrangements or harmonization of the the spatial data services.

Current research activities

Some research studies on how to use abstract workflow notations for generating and validating the behaviour of executable workflows [20] have been done. GENESIS FP7 project has in its research part the goal of using this initial result for defining a workflow development and management framework.

Important research studies are also aiming at adding semantic information at the service descriptions, usually based on annotations which decorate the syntactical service interface description (see e.g. SA-WSDL). This is particularly useful for spatial data services whose functionalities are very diverse and therefore human readable information illustrating what the service is offering is extremely relevant for the discovery and evaluation of Invoke services.

A proposal for Invoke Service

Taking into account what emerged in the previous sections a preliminary Invoke service definition is proposed. In particular it maps the use cases into operations and introduces how they could be implemented and encoded.

Operations

The Invoke service operations are summarized in Table 2.

Table 2 Invoke service interface

Operation	Description	Mandatory
Get service metadata	Provides the information for using the Invoke service and about the supplied spatial data services. As pointed out in Table 1 the details on how to use the Invoke operation	Yes

	significantly depends on the invoked spatial data service.	
Invoke spatial data service	Performs the (synchronous/asynchronous) invocation of the spatial data service and provides a mean for getting the result.	Yes[3]
Link spatial data services	Allows the declaration of the availability of a spatial data service for its invocation through the Member State Invoke service.	Yes

Get service metadata

Table 3 lists the information composing the Invoke service metadata and how they could be encoded with existing technologies.

Table 3 Invoke Service metadata

Element	Description	Technical solution
MD IR	All the metadata foreseen for spatial data services	See MD Technical Guidance for an example of encoding
Spatial data services	Describes the supplied spatial data services and their functionalities	(see Table 1 for current limitations) WSDL, OGC capabilities, …
Invoke operation interface	Operation interaction modalities (sync/asynch), service binding, parameters, etc.	(see Table 1 for current limitations) WSDL, OGC capabilities, …
Workflow	If applicable it describes the sequence of operations to be performed in order to invoke and get the result of the spatial data service	Choreography languages, BPMN, UML sequence diagrams, …
Service chain	If applicable it describes the sequence of (relevant) operations the invoke service performs and details about its handling (transparent/opaque chaining, required credentials for invoking involved services, etc.)	Choreography languages, BPMN, UML sequence diagrams, BPEL Additional metadata indicating how the chain execution is controlled.
Spatial data service access instructions	If applicable it describes how the user can directly access and use the spatial data service	URL of the spatial data service and additional info (e.g. user guide, user use conditions, …)

Invoke spatial data service

The parameters the invoke operation expects are to some extent depending on the specific characteristics of the invoked spatial data service.

<u>Request</u>

[3] If the spatial data service is directly accessible by human users it could simply return a reference to the capabilities document

The operation needs the information necessary for triggering the synchronous or asynchronous invocation of the spatial data service. The parameters will include all the parameters expected by the spatial data service whose encoding might however be rephrased in order to comply with a standardized encoding. Depending on the spatial data service implications (e.g. asynchronous result retrieval) it may include parameters indicating how to be notified (e.g. via callback or other even notification mechanisms) about result availability.

<u>Response</u>
The response can contain one of the following: a) the session identifier allowing the get in a second stage the result or monitor the execution state, b) the spatial data service result, c) the parameters for a second invoke operation invocation allowing to retrieve the result, or d) (a link to) the metadata document indicating how to directly access the spatial data service.

Link spatial data service

This operation requires at least the parameters identified in the previous section for the creation of the invoke spatial data service.

Technical solutions

The technologies supporting the Invoke service implementation are here summarized, considering also potential limitations:

- Spatial data service interface: WSDL or similar documents shall be used to describe spatial data services and this would not be anyway enough (see Table 1 Spatial data service description elements Table 1). Extensions at the OGC capabilities documents or creation of a separate spatial data service register are possible solutions. It is worth remark again that BPEL is able to invoke only services described through WSDL 1.1 (with any supported service bindings).
- Invoke service interface: considering the flexibility of the OGC Web Processing Service specification, and that the Invoke operation will vary significantly depending on the linked spatial data service, the usage of WPS standard could be beneficial to the Invoke service interface and encoding. However, some aspects like asynchronous invocations and WSDL description may require some further extensions.

Conclusion

This document introduces some of the challenges and explores the possible solutions at hand for the technical specification of the fifth Network Service TYPE “services allowing spatial data services to be invoked”. The dependency with the technical arrangements for the interoperability and, where practicable, harmonisation of spatial data sets and services is critical and both sets of implementing rules will have to be devised keeping this characteristic in mind.

The use cases and technological solutions are meant for consideration by the Network Services Drafting Team in the course of their drafting of the corresponding Implementing Rules.

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Annex on Spatial Data Services taxonomy

The scope of spatial data services foreseen in the INSPIRE directive is defined in the INSPIRE Metadata Regulation through the following metadata keywords element based on the geographic services taxonomy of EN ISO 19119. This taxonomy is organised in categories, the subcategories defining the value domain of the classification of spatial data services.

100 Geographic human interaction services (humanInteractionService)
This category comprises the following subcategories:

101 Catalogue viewer (humanCatalogueViewer)
Client service that allows a user to interact with a catalogue to locate, browse, and manage metadata about geographic data or geographic services.

102 Geographic viewer (humanGeographicViewer)
Client service that allows a user to view one or more feature collections or coverages.

103 Geographic spreadsheet viewer (humanGeographicSpreadsheetViewer)
Client service that allows a user to interact with multiple data objects and to request calculations similar to an arithmetic spreadsheet but extended to geographic data.

104 Service editor (humanServiceEditor)
Client service that allows a user to control geographic processing services.

105 Chain definition editor (humanChainDefinitionEditor)
Provides user interaction with a chain definition service.

106 Workflow enactment manager.(humanWorkflowEnactmentManager)
Provides user interaction with a workflow enactment service.

107 Geographic feature editor (humanGeographicFeatureEditor)
Geographic viewer that allows a user to interact with feature data.

108 Geographic symbol editor (humanGeographicSymbolEditor)
Client service that allows a human to select and manage symbol libraries.

109 Feature generalisation editor (humanFeatureGeneralizationEditor)
Client service that allows a user to modify the cartographic characteristics of a feature or feature collection by simplifying its visualisation, while maintaining its salient elements – the spatial equivalent of simplification.

110 Geographic data-structure viewer (humanGeographicDataStructureViewer)
Client service that allows a user to access part of data set to see its internal structure.

200 Geographic model/information management service (infoManagementService)
This category comprises the following subcategories:

201 Feature access service (infoFeatureAccessService)
Service that provides a client access to and management of a feature store.

202 Map access service (infoMapAccessService)
Service that provides a client access to a geographic graphics, i.e. pictures of geographic data.

203 Coverage access service (infoCoverageAccessService)
Service that provides a client access to and management of a coverage store.

204 Sensor description service (infoSensorDescriptionService)
Service that provides the description of a coverage sensor, including sensor location and orientation, as well as the sensor's geometric, dynamic, and radiometric characteristics for geo-processing purposes.

205 Product access service (infoProductAccessService)
Service that provides access to and management of a geographic product store.

206 Feature type service (infoFeatureTypeService)
Service that provides a client to access to and management of a store of feature type definitions.

207 Catalogue service (infoCatalogueService)
Service that provides discovery and management services on a store of metadata about instances.

208 Registry Service (infoRegistryService)
Service that provides access to store of metadata about types.

209 Gazetteer service (infoGazetteerService)
Service that provides access to a directory of instances of a class or classes of real-world phenomena containing some information regarding position.

210 Order handling service (infoOrderHandlingService)
Service that provides a client with the ability to order products from a provider.

211 Standing order service (infoStandingOrderService)
Order handling service that allows a user to request that a product over a geographic area be disseminated when it becomes available.

300 Geographic workflow/task management services (taskManagementService)
This category comprises the following subcategories:

301 Chain definition service (chainDefinitionService)
Service to define a chain and to enable it to be executed by the workflow enactment service.

302 Workflow enactment service (workflowEnactmentService)
The workflow enactment service interprets a chain and controls the instantiation of services and sequencing of activities.

303 Subscription service (subscriptionService)
Service to allow clients to register for notification about events.

400 Geographic processing services – spatial (spatialProcessingService)
This category comprises the following subcategories:

401 Coordinate conversion service (spatialCoordinateConversionService)
Service to change coordinates from one coordinate system to another coordinate system that is related to the same datum.

402 Coordinate transformation service (spatialCoordinateTransformationService)
Service to change coordinates from a coordinate reference system based on one datum to a coordinate reference system based on a second datum.

403 Coverage/vector conversion service (spatialCoverageVectorConversionService)
Service to change the spatial representation from a coverage schema to a vector schema, or vice versa.

404 Image coordinate conversion service (spatialImageCoordinateConversionService)
A coordinate transformation or coordinate conversion service to change the coordinate reference system for an image.

405 Rectification service (spatialRectificationService)
Service for transforming an image into a perpendicular parallel projection and therefore a constant scale.

406 Orthorectification service (spatialOrthorectificationService)
A rectification service that removes image tilt and displacement due to terrain elevation.

407 Sensor geometry model adjustment service (spatialSensorGeometryModelAdjustmentService)
Service that adjusts sensor geometry models to improve the match of the image with other images and/or known ground positions.

408 Image geometry model conversion service (spatialImageGeometryModelConversionService)
Service that converts sensor geometry models into a different but equivalent sensor geometry model.

409 Subsetting service (spatialSubsettingService)
Service that extracts data from an input in a continuous spatial region either by geographic location or by grid coordinates.

410 Sampling service (spatialSamplingService)
Service that extracts data from an input using a consistent sampling scheme either by geographic location or by grid coordinates.

411 Tiling change service (spatialTilingChangeService)
Service that changes the tiling of geographic data.

412 Dimension measurement service (spatialDimensionMeasurementService)
Service to compute dimensions of objects visible in an image or other geodata.

413 Feature manipulation services (spatialFeatureManipulationService)
Register one feature to another, an image, or another data set or coordinate set; correcting for relative translation shifts, rotational differences, scale differences, and perspective differences. Verify that all features in the Feature Collection are topologically consistent according to the topology rules of the Feature Collection, and identifies and/or corrects any inconsistencies that are discovered.

414 Feature matching service (spatialFeatureMatchingService)
Service that determines which features and portions of features represent the same real world entity from multiple data sources, e.g., edge matching and limited conflation.

415 Feature generalisation service (spatialFeatureGeneralizationService)
Service that reduces spatial variation in a feature collection to increase the effectiveness of communication by counteracting the undesirable effects of data reduction.

416 Route determination service (spatialRouteDeterminationService)
Service to determine the optimal path between two specified points based on the input parameters and properties contained in the Feature Collection.

417 Positioning service (spatialPositioningService)
Service provided by a position-providing device to use, obtain and unambiguously interpret position information, and determines whether the results meet the requirements of the use.

418 Proximity analysis service (spatialProximityAnalysisService)
Given a position or geographic feature, finds all objects with a given set of attributes that are located within a user-specified distance of the position or feature.

500 Geographic processing services – thematic (thematicProcessingService)
This category comprises the following subcategories:

501 Geoparameter calculation service (thematicGoparameterCalculationService)
Service to derive application-oriented quantitative results that are not available from the raw data itself.

502 Thematic classification service (thematicClassificationService)
Service to classify regions of geographic data based on thematic attributes.

503 Feature generalisation service (thematicFeatureGeneralizationService)
Service that generalises feature types in a feature collection to increase the effectiveness of communication by counteracting the undesirable effects of data reduction.

504 Subsetting service (thematicSubsettingService)
Service that extracts data from an input based on parameter values.

505 Spatial counting service (thematicSpatialCountingService)
Service that counts geographic features.

506 Change detection service (thematicChangeDetectionService)
Service to find differences between two data sets that represent the same geographical area at different times.

507 Geographic information extraction services (thematicGeographicInformationExtractionService)
Services supporting the extraction of feature and terrain information from remotely sensed and scanned images.

508 Image processing service (thematicImageProcessingService)
Service to change the values of thematic attributes of an image using a mathematical function.

509 Reduced resolution generation service (thematicReducedResolutionGenerationService)
Service that reduces the resolution of an image.

510 Image Manipulation Services (thematicImageManipulationService)
Services for manipulating data values in images: changing colour and contrast values, applying various filters, manipulating image resolution, noise removal, "striping", systematic-radiometric corrections, atmospheric attenuation, changes in scene illumination, etc.

511 Image understanding services (thematicImageUnderstandingService)
Services that provide automated image change detection, registered image differencing, significance-of-difference analysis and display, and area-based and model-based differencing.

512 Image synthesis services (thematicImageSynthesisService)
Services for creating or transforming images using computer-based spatial models, perspective transformations, and manipulations of image characteristics to improve visibility, sharpen resolution, and/or reduce the effects of cloud cover or haze.

513 Multiband image manipulation (thematicMultibandImageManipulationService)
Services that modify an image using the multiple bands of the image.

514 Object detection service (thematicObjectDetectionService)
Service to detect real-world objects in an image.

515 Geoparsing service (thematicGeoparsingService)
Service to scan text documents for location-based references, such as a place names, addresses, postal codes, etc., in preparation for passage to a geocoding service.

516 Geocoding service (thematicGeocodingService)
Service to augment location-based text references with geographic coordinates (or some other spatial reference).

600 Geographic processing services – temporal (temporalProcessingService)
This category comprises the following subcategories:

601 Temporal reference system transformation service (temporalReferenceSystemTransformationService)
Service to change the values of temporal instances from one temporal reference system to another temporal reference system.

602 Subsetting service (temporalSubsettingService)
Service that extracts data from an input in a continuous interval based on temporal position values.

603 Sampling service (temporalSamplingService)
Service that extracts data from an input using a consistent sampling scheme based on temporal position values.

604 Temporal proximity analysis service (temporalProximityAnalysisService)
Given a temporal interval or event, find all objects with a given set of attributes that are located within a user-specified interval from the interval or event.

700 Geographic processing services – metadata (metadataProcessingService)
This category comprises the following subcategories:

701 Statistical calculation service (metadataStatisticalCalculationService)
Service to calculate the statistics of a data set.

702 Geographic annotation services (metadataGeographicAnnotationService)
Services to add ancillary information to an image or a feature in a feature collection.

800 Geographic communication services (comService)
This category comprises the following subcategories:

801 Encoding service (comEncodingService)
Service that provides implementation of an encoding rule and provides an interface to encoding and decoding functionality.

802 Transfer service (comTransferService)
Service that provides implementation of one or more transfer protocols, which allows data transfer between distributed information systems over offline or online communication media.

803 Geographic compression service (comGeographicCompressionService)
Service that converts spatial portions of a feature collection to and from compressed form.

804 Geographic format conversion service (comGeographicFormatConversionService)
Service that converts from one geographic data format to another.

805 Messaging service (comMessagingService)
Service that allows multiple users to simultaneously view, comment about, and request edits of feature collections.

806 Remote file and executable management (comRemoteFileAndExecutableManagement)
Service that provides access to secondary storage of geographic features as if it were local to the client.

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Abstract

The aim of this study is to investigate the requirements and challenges for the development of INSPIRE Invoke services specifications. Invoke services provide a mean for invoking INSPIRE spatial data services, thus the dependencies between the Invoke and spatial data services are reflected in this study. In particular, the spatial data service interoperability arrangements study has recently started and here we anticipate some assumptions on spatial data service characteristics that will be used to define the context within which the Invoke development issues will be analyzed. Consequently this study will be validated, and eventually updated, against the spatial data service interoperability arrangements once it will be released.

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