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From Here to Eternity: An Experiment Applying the e-Framework Infrastructure for Education and Research and the SUMO Ontology to Standards-based Geospatial Web Services*

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Abstract

A number of efforts have been made in recent years to define standards for the description of resources (including web services) in services oriented architectures. These standards often use description logic ontologies (for example, OWL-S) and are intended to be machine-readable. They have been applied to geospatial web services to describe the functions that those services perform in a way that can be automatically interpreted by systems. By contrast, little effort has gone into the development of human readable descriptions of resources in a services oriented architecture, other than using unstructured natural language. e-Framework is an infrastructure for the higher education environment that provides a typology of human-readable artefacts that can be used to describe resources, and provides an internal structure for those artefacts. e-Framework has thus far not been used with geospatial information even though geospatial information has a number of important roles in education and research, and has a well-organised community of users and creators.

This paper applies the e-Framework infrastructure to OGC web services, and also recommends the refinement of e-Framework with the use of the SUMO Upper Level Ontology to define Service Genres, the most abstract level of artefacts in e-Framework. It then illustrates the ways in which the Open Geospatial Consortium standards and specifications may be described in e-Framework. The work evaluates SUMO for e-Framework purposes, finding that its use for Service Genres is possible and offers a number of gains. It also

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evaluates e-Framework from a geospatial perspective, and shows that e-Framework's constraints on resource descriptions do not suit the large and complex nature of geospatial web services.

Keywords: services oriented architecture, OGC, ontology, geospatial, education

1 INTRODUCTION

e-Framework¹ is a services-oriented infrastructure that provides resources to support education and research with the intention of promoting discovery and reuse of such components across educational institutions. The e-Framework infrastructure consists of a typology of descriptive artefacts together with actual instances of those artefacts to describe the resources within the infrastructure. The descriptive artefacts differ from existing, established methods for describing web services in that they are intended to be human-readable, rather than machine-readable, and in this way the e-Framework approach may supplement existing approaches to web services description. This is useful in assisting potential users of web services to evaluate the web services for their purposes.

This paper applies the e-Framework infrastructure to the geospatial domain, focussing on web services using standards from the Open Geospatial Consortium (OGC) as representatives of interoperable, standards-based components within a spatial data infrastructure. The work described in this paper is the first main application of e-Framework to an organised domain (although individual web services have previously been described). Specifically, the work uses e-Framework to describe a collection of web services created as part of the SEE-GEO project². In the process of doing this, it proposes the standardisation of the Service Genres used within e-Framework using part of the SUMO Upper Level Ontology (Niles and Pease, 2001), illustrates how OGC web services can be described with the e-Framework artefacts, and evaluates the suitability of e-Framework for describing geospatial web services, together with issues that arise from the general nature of some OGC web services.

The outline of the paper is as follows: Section 2 summarises related work using information infrastructures in education and research (including e-Framework), with a particular focus on the geospatial aspects of such work; Section 3 describes e-Framework, including its history and purpose, explains the e-Framework typology of artefacts and provides an information model for this typology, and explains how e-Framework descriptions compare to other methods for describing web services; Section 4 presents the SEE-GEO case study and describes the web services therein; Section 5 discusses the issue of

¹ <http://www.e-framework.org/>

² <http://edina.ac.uk/projects/seesaw/seegeo/>

standardising the e-Framework Service Genres and proposes and evaluates the use of SUMO for this purpose, as well as considering other possible existing sets of geospatial operations; Section 6 illustrates how the SEE-GEO web services can be described using SUMO Service Genres from Section 5, Service Expressions and Service Usage Models and evaluates the e-Framework artefacts for describing OGC web services. Finally, Section 7 describes future research.

The main contribution of this work is to show how OGC web services can be described in a structured, human-readable form as part of a broader, non-spatially specific infrastructure (and thus be described in a way that is compatible with non-spatial web services). Consequent but also important contributions arise from the discussion of the various issues that arise from the work, including appropriate typologies of abstract geospatial activities; issues arising from the granularity of OGC web services and their inclusion in systems with non-OGC web services and the evaluation of e-Framework.

2 RELATED WORK

The last decade has seen the development of information system architectures that are increasingly modular. Modularisation involves creating components that provide a particular function and can then be assembled and combined to perform business processes. If such modules conform to recognised standards, it is possible for individuals and organisations to share modules, to mix and match and to avoid the need to duplicate effort by creating a function that already exists. The use of standards allows parties to interpret the functionality of modules created by other parties and to develop generic tools for modules that conform to those standards.

Recent years have seen the development of architectures that use interoperable, standards-compliant modules called web services. Such architectures are referred to as Services Oriented Architectures (SOAs). Web services are modularised programmes that perform a particular function and can be accessed over the Internet (Erl, 2004). Various international standards bodies have been involved in developing standards to be used for web services, most prominently including OASIS and W3C. In the geospatial context, most web services standards are developed by ISO TC 211 and the Open Geospatial Consortium (OGC). Some of the ISO TC 211 standards began their lives as OGC standards.

A large number of SOAs have been and are being developed across the world, ranging from organisation-specific SOAs to global SOAs around a particular theme (for example, the Global Spatial Data Infrastructure). SOAs have also been used widely within the education and research sectors. Of most interest for the current work are SOA efforts that operate across a number of organisations

to combine resources and make them available widely and in an interoperable manner. Examples of such efforts include the Coastal and Marine Perception Application for Scientific Scholarship (COMPASS), the European Academic Persistent Test Bed, the AuScope Spatial Information Services Stack and e-Framework. Each of these is briefly discussed below.

The COMPASS³ project developed a prototype knowledge infrastructure. The knowledge infrastructure was an ontology-driven SOA to support researchers and scientists in discovering and accessing scientific resources, including web services. The prototype used the marine and coastal domain, and included spatial information conforming to OGC standards, but is broadly applicable across all domains and for different types of information (Stock et al, 2009).

The European Academic Persistent Test Bed (PTB) is in its early stages and intends to develop a spatial data infrastructure (SDI) to be used as a platform for research and teaching across Europe (SOAs with a spatial focus are sometimes referred to as spatial data infrastructures within the geospatial community). A particular focus is the provision of a stable hardware and software environment that can be used for experimentation and to allow comparison of different approaches (Hobona et al, 2009).

The AuScope Spatial Information Services Stack (SISS)⁴ is a set of software components, services and functional capabilities that are needed to promote an environment for sharing of spatial information in Australia and that conform to ISO and OGC standards. Specifically, this will include a registry to allow access to a number of important spatial data repositories.

All of these efforts focus on different aspects of the development of Services Oriented Architectures for research and academia. COMPASS focuses on intelligent discovery and tools to support scientists; the PTB at this stage is focussing on the networking and organisational aspects of SOA formation and the particular technical challenges of an SOA that is flexible enough to be used for research; and the SISS focuses on the creation of software components and governance mechanisms for a spatial SOA.

e-Framework, the subject of this paper, focuses on the description of resources within an SOA, and as such, the work under this project may be useful for, and is compatible with, the work being completed under the other projects. The next Section provides more detail about e-Framework, the descriptive artefacts it uses, and how those artefacts compare with other approaches to the description of web services within an SOA.

³ <http://compass.edina.ac.uk/>

⁴ http://www.pfc.org.au/pub/Main/NeATsiss/SISS_ARCS_BP.pdf

3 THE E-FRAMEWORK INFRASTRUCTURE FOR EDUCATION AND RESEARCH

3.1 e-Framework Background, Objectives and History

The e-Framework for education and research is a joint initiative between the United Kingdom's Joint Information Systems Committee (JISC); Australia's Department of Education, Science and Training; New Zealand's Ministry of Education and the Netherlands' SURF. Its primary goal is to facilitate technical interoperability within and across education and research through improved strategic planning and implementation processes. Its particular guiding principles include a services oriented approach; open standards; community involvement; collaboration and flexible and incremental deployment (e-Framework, 2006; Olivier et al, 2005).

The motivation behind e-Framework was the desire to improve efficiency in development by improving coherence in work being done across the research and education sectors. It was recognised that much work was being done in the research and education sectors towards the development of web services, but that more coherence, knowledge of what had been developed, and a strategy for future development would provide institutions with information about which resources were ready for mainstream use, and allow more development to take place with a fixed amount of funding. Also, it was hoped that institutions could be encouraged to adopt compatible technologies through the provision of an infrastructure like e-Framework.

e-Framework's specific purposes are:

- to provide a strategic approach to technical infrastructure development within and across domains;
- to provide a consistent technical vocabulary;
- to provide a focal point for software developers and those providing services to education and research and
- to act as a catalyst for the development of further specifications and standards.

As a core part of meeting these purposes, e-Framework includes a knowledge base to pull together information and make it available to partners, institutions and developers. The knowledge base is composed of:

- a set of services and their descriptions;
- sets of service usage models (SUMs) describing how services may be used and
- guides, methodologies and analyses.

e-Framework came into being around 2005, and grew out of two earlier initiatives: the e-Learning Framework and the JISC Information Environment. Thus far, work on e-Framework has mainly focussed on the creation of e-Framework artefacts to describe information resources (e.g. web services). These artefacts include Service Genres, Service Expressions and Service Usage Models (see Section 3.2). The descriptions provided in these artefacts are human readable, and allow users and developers to identify resources that may be used for their work. Section 3.3 discusses in more detail the relationship between these machine readable artefacts and other methods for describing web services (including machine-readable methods and metadata).

Thus far, only a limited number of artefacts have been created, mainly by the project partners themselves (for example JISC) in connection with their funded projects. e-Framework has not yet been widely applied across a particular domain.

One of the objectives of this work was to apply e-Framework in a more comprehensive and systematic way across a domain, to identify any issues in applying e-Framework in this way and to evaluate the outcomes. The geospatial domain was chosen because it has a set of standards that are used internationally across different disciplines for geospatial web services (see Section 3.4).

3.2 The e-Framework Artefacts

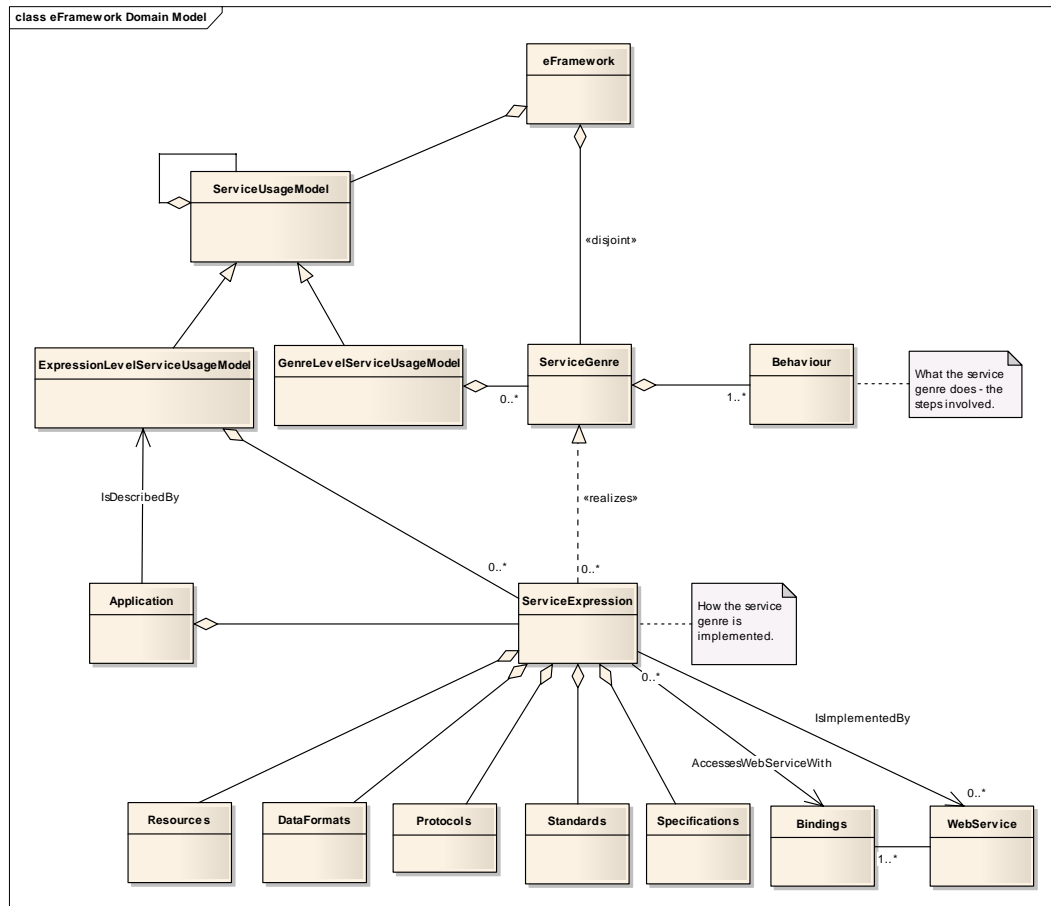
e-Framework uses a typology of artefacts to describe web services at two levels of abstraction with Service Genres and Service Expressions, and to describe business processes that combine and use the web services to achieve particular purposes with Service Usage Models.

The e-Framework artefacts work in conjunction with the Upper Layer (Howard et al, 2007). This Upper Layer is not part of e-Framework, but is used to describe business processes and workflows within a higher education institution from a non-technical point of view.

Figure 1 provides an overview and information model for the e-Framework artefacts (the notation in the diagram is Unified Modelling Language, or UML (Object Management Group, 2007)), and is followed by a description of each of the artefacts. More detail, examples and templates can be seen on the e-Framework web site⁵ and in the Appendices to this paper. Each artefact has a particular structure, with specific components being required.

⁵ <http://www.e-framework.org/>

Figure 1: UML Model of the e-Framework Artefact Information Model



3.2.1 Service Genres

A Service Genre is a generic activity or action, including a set of related behaviours in support of a process. For example, a Delivery Genre might represent the steps: track delivery; notify sender; notify recipient; release delivery. A Genre corresponds to a single verb, and examples include Classify, Harvest, Search and Translate; it is conceptual and abstract in nature and does not describe details of implementation (Nicholls, 2008).

In e-Framework, a Service Genre is described with a textual document that includes the name; rationale; classifications of domain, maturity, deployment scale and confidence level; version history; description; functionality; usage scenarios; standards; requests and behaviours for the Genre.

3.2.2 *Service Expressions*

A Service Expression is a particular way to realise a Service Genre, and includes implementation details. A Service Expression may reference and/or describe an implementation of existing specifications and standards, and may also reference data formats and protocols, and is likely to be implemented by a web service or set of web services (Nicholls, 2008). The work in this paper provides examples of Service Expressions that describe implementations of particular OGC specifications, and are implemented by OGC web services that conform to those specifications.

Any given Service Genre may be realised by many different Service Expressions, each representing a particular implementation (for example, there are many different implementations of the Search Genre, depending on what is being searched and how, and the standards and technologies being used), but a Service Expression is usually an expression of only one Service Genre.

The detailed description of a Service Expression can be used to design an implementation of the action or activity associated with the Service Genre, and may reference particular standard specifications and web services (Nicholls, 2008).

In e-Framework, a Service Expression is described by a textual document that includes similar information to a Service Genre, together with additional details regarding the technical implementation binding and design. It might be considered a kind of specification of the web service that implements it (see Figure 1), and contains much more detailed information that may be of interest to a human than the existing description standards that are designed for machine reading (see Section 3.3 for a discussion about how these descriptions relate to other approaches to the description of web services).

3.2.3 *Service Usage Models*

A Service Usage Model (SUM) is a model of how the components within the infrastructure (Service Genres, Service Expressions and the web services that implement them) meet business needs. A SUM describes the processes, policies and workflows involved in a domain, and shows how a structured collection of Service Genres or Service Expressions may be used to implement a software application (Nicholls, 2008).

Service Usage Models can be created at either the Expression level or the Genre level, according to whether they represent a generic use of the components or a more specific implementation use (Nicholls, 2008). The core elements of the

SUM description are similar to those for a Service Genre, with the addition of information about the business process and related diagrams.

3.2.4 The Upper Layer

The three e-Framework components and their supporting objects give a view of the infrastructure that is designed mainly for analysts, architects and developers who may be interested in understanding or using components created by other e-Framework institutions and parties.

Related to these e-Framework components is an Upper Layer that describes higher level processes and workflows within higher education institutions. This Upper Layer takes a high level business process management view, and is likely to ultimately be linked to the e-Framework components in a broader structure.

Specifically, the upper layer describes use cases, scenarios and projects, as well as taxonomies that are specific to a particular domain (Howard et al 2007). It is usually used to describe the types of use cases or scenarios within a particular part of the higher education sector (for example, student assessment), and represents a much less technical view than the e-Framework components themselves (Service Genres, Service Expressions and SUMs) that would be marshalled in support of a use case or scenario. Instead of describing web services and their use, the Upper Layer focuses on the generic functions and roles conducted by higher education institutions. An analysis of a part of the higher education sector using the Upper Layer may then be used to ensure strategic and appropriate development of e-Framework components.

3.3 The Relationship between e-Framework and Other Approaches to Description of Resources

Section 3.2 has outlined the e-Framework approach to describing components (particularly web services and their interactions) within an SOA. This approach focuses on creating documents that are human readable. However, a number of other approaches to the description of web services have been advanced by other researchers.

Table 1 summarises some of the main alternative approaches and the elements and formats they use to describe web services. Each of these approaches and their respective roles (relative to e-Framework) are discussed in more detail in this Section.

Table 1: A Comparison of Approaches to Web Service Description

Element	e-F Serv Genre	e-F Serv Expr	e-F SUM	WSDL	UDDI	OGC GetC ⁶	OWL- S	WSM O	ISO 191 19
Name	NL	NL	NL	NL	NL	NL	NL	NL	NL
Rationale/Purpose	NL	NL	NL						NL
Version	NL	NL	NL			NL			NL
Submitter Name (contact person and/or organizations)	NL	NL	NL		NL	NL	NL	NL	NL
Submitter Description					NL				
Submitter Classification					C				
Submitter Web Site						XML			
Keywords/Topic Classification						NL	NL	NL	
Description/Abstract	NL, D	NL, D	NL, D		NL	NL	NL	NL	NL
Functionality	NL, D	NL, D	NL, D				OWL	OWL	
Behaviours and Requests	NL, D	NL, D					OWL	OWL	
Use and Interactions	NL, D	NL, D							
Usage Scenarios	NL, D	NL, D	NL, D						
Applicability	NL	NL	NL						
Structure	NL, D	NL, D	NL, D						
Applicable Standards	NL	NL	NL			C			
Design Decisions and Trade-offs	NL	NL	NL						
Implementation Guidance and Dependencies	NL, D	NL, D	NL, D						
Known Uses	NL	NL	NL						
Business Process Modelling			NL, D				OWL	OWL	
SUM Diagram			D						
Data Sources Used			NL						
References			NL						
Notation			NL						
Terms	NL	NL	NL						
Service/Operation				XML	As for WSDL	XML	As for WSDL ⁷	As for WSDL	NL
Port/Endpoint				XML		XML			NL
Binding				XML		XML			NL
PortType/Interface				XML		XML			NL
Operation				XML		XML			NL

⁶ The GetCapabilities content varies depending on the OGC specification that the service conforms to. This table identifies the common elements that appear in all OGC specifications.

⁷ Use of WSDL is not mandatory for describing OWL-S bindings. Other formats may also be used to represent the same information.

Message				XML		XML			
Types				XML		XML			
Fee and Access Details						NL			NL
Parameter Values and Constraints						XML	OWL	OWL	NL
User Goals								OWL	

NL = Natural Language; D = diagrammatic; C = code; N = numerical; XML = Extensible Markup Language;
 OWL = Web Ontology Language

3.3.1 Non-Ontology Web Service Descriptions

A number of approaches to the description of web services have been suggested that do not use ontologies. Examples include WSDL (Web Service Definition Language) (Christensen et al, 2001), UDDI (Clement et al 2004) and the GetCapabilities documents used by OGC web services (Whiteside, 2007). WSDL and UDDI (a registry standard) are intended to be machine-readable, providing content in a sufficiently structured manner to allow software to be developed to automatically use the description to run the web service. WSDL and UDDI thus focus on the binding information that is needed to execute web services without manual intervention.

The OGC web service standards define a GetCapabilities document to describe conforming web services. This document is a hybrid of human-readable and machine-readable content. It is structured using XML, but the contents of the XML elements are largely natural language. GetCapabilities can be used by machines to execute web services without intervention, and also includes some basic human-readable content that could be displayed to assist users in interpreting the web service.

3.3.2 Web Service Ontologies

Web service ontologies like OWL-S (Martin et al, 2004) and WSMO (Steinmetz and Toma, 2008) were developed for machine-readable and inference purposes. They include descriptions of functionality provided by the web service and the processes it performs in achieving its outcomes in a structured form with the aim of supporting automatic service discovery and orchestration (Lara et al, 2004). They contain very limited human-readable content. Examples of work exploring the use of web service ontologies for semantic matching, discovery and orchestration include Ganjisaffar et al (2006) and in the geospatial context, SWING (Roman et al 2007), eMerges (Tanasescu et al 2007) and Lutz (2007).

3.3.3 Metadata

Metadata is usually defined as data about data, meaning that it consists of information about data sets (Honle *et al* 2005). Dublin Core⁸ is one of the most popular metadata standards, defining a set of core terms to describe information resources.

In recent years metadata about web services has also been created, and the most common standard for such metadata in the geospatial field is ISO 19119 (International Standards Organisation, 2005).

Metadata is usually organised in a structured way, consisting of attributes or short textual descriptions about the information resource (in this case, a web service). As can be seen in Table 1, ISO 19119 consists of a number of natural language items, but these are usually atomic and stored in a database and/or registry.

While e-Framework has some overlaps in content with many of these different approaches to the description of web services, it mainly differs from these approaches in that it provides long, detailed textual information about the resource concerned (see Appendices A to C for examples). These textual descriptions may include diagrams, justifications, decision processes and usage scenarios. In contrast, the other approaches are usually much briefer or machine-readable rather than human-readable.

In this way, the e-Framework artefacts may be considered akin to a functional specification for a web service or generic activity, but differ from such specifications in that they conform to a standardised structure and are available as part of a public knowledge base. This is useful because it allows other potential users of the web services (and related resources) to be aware of their existence and evaluate them.

This research does not claim that the e-Framework artefacts replace the need for other, machine-readable, indexable descriptions of web services, but that they provide an additional description that is useful in assisting the evaluation of resources for reuse and strategic planning.

3.4 e-Framework and OGC Web Services

e-Framework has not previously been used with geospatial web services, and prior to this work, had not been systematically applied across a domain. The geospatial domain was selected for the first domain-wide application of e-Framework because it has a defined set of open web service standards

⁸ <http://dublincore.org/>

developed by an international consortium that can be used to share geospatial information, and are widely used internationally.

e-Framework is designed to describe web services, and thus fits well with the geospatial domain. The work does not claim that the OGC web services define the entire geospatial domain or all activities and services within it, but simply uses the OGC web services as a representation of the geospatial domain.

The work described in this paper specifically identifies how geospatial web services might be represented using e-Framework. Geospatial web services are expected to be useful within the e-Framework context because many activities in higher education institutions make use of geospatial information. Teaching and research are prime candidates for this, and the case study presented in Section 4 is an example of a group of geospatial web services that were used to support higher education students. Geospatial information is also used for administrative purposes in higher education institutions. Examples of such uses include the management of physical resources (buildings, car parks, etc.), the analysis of student origin and residence and the identification of suitable locations for new teaching centres.

4 THE CASE STUDY

The application of e-Framework to geospatial web services was driven by the SEE-GEO⁹ project. As part of this project a web portal was developed that made use of a number of different web services (including OGC web services) and performed geolinking to combine different data sets for the user. This Section provides a user scenario and describes the main web services involved in the portal that is included in this scenario.

4.1 User Scenario

A student is engaged in research concerning provision of social services in the UK and health improvement. She needs information about the geographical distribution of British health status. This information is not available from a single source, so she uses a geolinking web portal to collect and combine data from two sources.

The student opens a web browser window and logs into a web portal. She first wants to find the geographic area of interest. She realises she can do this in three ways: from a drop down list which contains all areas/regions in the UK; from a bounding box coordinate input field which allows her to enter coordinate values or by simply dragging a box on a map. She selects "Leeds Local Authority

⁹ <http://edina.ac.uk/projects/seesaw/seegeo/>

District” from the drop down box. Accordingly, a list of census attributes appears in the Census Attribute selection area. She selects the desired census attribute: 'Limiting Long Term Illness', then presses the Map Creation button. Before processing the requests, the system asks her which map format she prefers: using a default Schema or Styled Layer Descriptor. He chooses the default setting.

The Geolinking Service pulls the requested data from two distributed data sources: the attribute data is obtained from MIMAS¹⁰ (a data centre that provides census data), and the geospatial boundary data is retrieved from EDINA¹¹ (a data centre that provides a range of geospatial data sets to the higher education sector). The result is then used to create a Mapping Service that is displayed along with relevant information on the ranges of the attribute being mapped.

The student also obtains additional information and can easily view the figures with their graphic locations in the map. She simply downloads and inserts the new map image into her report.

4.2 The Web Services

The web portal described in the user scenario combines a number of different web services to provide the resulting map. These web services are:

1. An OGC Web Feature Service makes available data about UK borders, including census districts.
2. A non-spatial web service makes available census statistics.
3. An OGC Geolinked Data Access Service converts data from the non-spatial web service into an XML stream as input into the Geolinking Web Service.
4. An OGC Geolinking Web Service takes data from the OGC Geolinked Data Access Service and an OGC Web Feature Service and links the two data sets together with a common identifier.
5. An OGC Web Map Service generates and displays a map in the desired map format.

This scenario and set of web services was used to drive the application of e-Framework to geospatial web services, but a wider view of the geospatial domain was considered. The work specifically involved three activities:

- an examination of the existing set of Service Genres included in e-Framework and their suitability for the representation of geospatial activities in the context of open standards;
- an analysis of all of the OGC web services to determine which e-Framework artefacts best represent them and

¹⁰ <http://mimas.ac.uk/>

¹¹ <http://edina.ac.uk/>

- the description of the web services used in the SEE-GEO project using e-Framework artefacts.

These activities are discussed in the following Sections, and used to evaluate the suitability of e-Framework for geospatial web services, with a view to identifying any necessary improvements or modifications. As a corollary, the granularity of the OGC web services is also discussed in terms of its application to e-Framework. The discussion is supplemented by Appendices containing actual examples of the e-Framework artefacts for the user scenario.

5 STANDARDISING E-FRAMEWORK SERVICE GENRES WITH SUMO

The set of e-Framework Service Genres that existed prior to this work was not based on any particular standard or theoretical work, but rather on the requirement to document existing web services and the expected future requirements for such web services, and was not necessarily complete or suitable in a geospatial context.

One of the goals of the work was to determine whether the Service Genres would be sufficient to describe geospatial information, and if not, to propose a set that would. It was also considered desirable to take advantage of previous efforts to define both geospatial activities and operations, and more generic (not specifically geospatial) activities and operations, and thus potentially standardise the e-Framework Service Genres. In this way, previous extensive effort in defining such operations could be utilised, proliferation of standards and approaches reduced, and the work undertaken in this project would be more likely to be coherent with existing work in the geospatial domain and the broader information management community.

5.1 Alternative Bases for the Service Genres

A number of sets of geospatial operations have already been proposed (for example, Albrecht, Chrisman, Lemmens, ISO 19119), and these were evaluated for their suitability for e-Framework. Furthermore, the abstract forms of many geospatial operations are sufficiently generic to apply across a range of domains, so existing generic sets of operations (not specific to the geospatial context) were also considered (SUMO, DOLCE).

Albrecht (1995) provides a classification of geo-operations that focuses on search and analysis (for example, Locational Analysis including Buffer, Overlay, etc), Terrain Analysis, Neighbourhood Analysis), but does not include creation, destruction or editing of geospatial objects. Other similar analysis-focussed taxonomies are provided by Chrisman (1999), Tomlin (1990) and described by Giordano *et al* (1994).

Lemmens (2006) provides a typology of geo-operations with varying levels of detail. While some of his geo-operations are quite generic (for example, Overlay, Interpolate), others are very specific and information focussed (for example, ExtractGeoInfoFromStream, MetadataInteract).

ISO 19119 (International Standards Organisation, 2005) is an international standard that includes a geographic services taxonomy. This taxonomy provides a high level set of services, some of which map directly to the OGC Web Service Specifications. Examples include geographic viewer (with specialisations for mosaicing, animation, etc), geographic symbol editor, workflow enactment manager, map access service and order handling service.

In addition to these geospatial typologies, two upper level ontologies were also examined. Upper level ontologies are intended to define generic objects and processes that may then be applied and specialised in the context of particular domains, and given the purpose of Service Genres, these ontologies were considered likely candidates for the definition of generic operations that would also be appropriate in the non-spatial context. DOLCE and SUMO are two prominent upper level ontologies, and are briefly described here.

DOLCE is an upper level ontology developed at the Laboratory for Applied Ontology of the Italian National Research Council, and is gaining increasing support as a basis for domain specific ontologies, which specialise from it (for example, Brodaric 2008). DOLCE contains a branch for Perdurants (processes), but does not further subdivide beyond the notion of a Flux Process, so does not provide significant detail in regard to processes.

SUMO is the Suggested Upper Merged Ontology, was created at Teknowledge Corporation as source for the IEEE Standard Upper Ontology Working Group and is now owned by the IEEE. Together with its domain ontologies, it is the largest formal public ontology, and has an extensive set of generic processes. These are divided into five main categories: Dual Object Process, Intentional Process, Shape Change, Internal Change and Motion, and then further specialised to varying levels depending on requirements. Examples of lower-level processes include Create, Search, Substitute, Compare, Combine, Separate and Publish (Niles and Pease, 2001).

SUMO was considered most appropriate as a basis for the Service Genres in the e-Framework geospatial domain plan for a number of reasons. Firstly, the ontology is generic, and some of the concepts included in SUMO already map to existing Service Genres in e-Framework (for example, Search), minimising the effort required to standardise the existing Service Genres. The Service Genres are not intended to be domain-specific, although it is recognised that in some cases, Genres that relate particularly to one domain may be required. Thus the

use of SUMO should allow a set of Service Genres that apply across e-Framework to be developed, without requiring an entirely separate set of Genres for the geospatial domain. Secondly, of the ontologies examined, SUMO had the best set of operations or processes. Thirdly, SUMO seemed a better fit with the Service Genre objectives and principles than the other typologies examined, including the non-ontology typologies, most of which were either too specific (for example, Lemmens, 2006) or non-atomic (for example, International Standards Organisation, 2005). Fourthly, SUMO provides a fairly complete picture of generic processes, but can be extended if required. Finally, a number of software tools have been created to help users to work with SUMO (for example, the Sigma Knowledge Engineering Environment), and thus work with SUMO based Service Genres is already partially supported.

SUMO was adapted for use in e-Framework by the selection of the concepts within the ontology that could validly be used as Service Genres. This is needed because the e-Framework model for Service Genres allows only one level of Genres – Genres are not permitted to be specialisations of one another. Therefore, the most appropriate SUMO concept was selected as the Service Genre.

5.2 The Relationship with Existing e-Framework Service Genres

Table 2 lists the e-Framework Service Genres and describes their relationship to SUMO concepts with a view to identifying whether it would be practical to adopt the SUMO concepts as a complete set of Service Genres (thus migrating from the existing e-Framework Genres where they do not match a SUMO concept). The genres listed here are the result of a recent review (Rehak 2008).

Table 2: The Relationship between Existing e-Framework Service Genres and SUMO Concepts

Existing e-Framework Service Genre (post-Review)	Related SUMO Concept	Relationship
Alert	State	Alert is a specialisation of State, involving a particular type of statement. Other types of statement are possible.
Annotate	Includes Create, Update and Delete Annotation.	Annotate can be represented in the same way as Create, Update and Delete. These operations are generic and could apply to annotations, geospatial information or other items.
Archive	Keep	Archive is a specialisation of Keep.

Audit	Compare	The Audit genre is described as a comparison of changes against a set of policies or procedures, so maps well to the Compare SUMO concept. Again, it is a particular type of comparison, indicating a specialisation.
Authenticate	RegulatoryProcess, Manage	Authenticate may be considered a specialisation of RegulatoryProcess or Manage, although both are much more general.
Authorise	RegulatoryProcess, Manage	Authorise may be considered a specialisation of RegulatoryProcess or Manage, although both are much more general.
Classify	Classify	Exact equivalent.
Comply	Commit	Comply is designed to allow users to agree to terms and conditions. It is a specialisation of commit.
Create (currently Add)	Create	Exact equivalent.
Delete (currently Add)	Destroy	Exact equivalent.
Deposit	Put	Deposit may be considered a specialisation of Put.
Email	Express, State	Email is a specialisation of Express, involving a particular type of expression.
Generate	Create	Generate is a specialisation of Create, in which an object is created using a particular type of process.
Harvest	Get	Harvest is a specialisation of Get.
Log	Keep	Log is a specialisation of Keep.
Lookup (currently Dictionary, Thesaurus)	Select, Read, Search	Lookup returns a value that relates to a given word. This function may be considered a specialisation of Select, Read or Search.
Manage Members	Manage	Manage Members is a specialisation of Manage.
Messaging	Express, State	Messaging is a specialisation of Express.
Obtain	Get	Exact equivalent.
Package	Combine, Classify	Package is a combination of Combine and Classify.
Presence	Declare	Presence (which involves a user announcing her or her presence) is a specialisation of Declare.

Rate	Classify	Rate (score) is a specialisation of Classify.
Read	Read	Exact equivalent.
Recommend	Publish	Recommend might be considered one case of Publish, in which a user publishes a recommendation. This is not a close match though.
Register	Create, Manage	Register is a combination of Create and Manage.
Resolve	Select	Select is a specialisation of Resolve.
Search	Search	Exact equivalent.
Syndicate	Publish	Syndicate is a specialisation of Publish.
Transform	StateChange, ShapeChange, SurfaceChange	Transform is a generalisation of StateChange, ShapeChange and SurfaceChange.
Translate	Substitute	Translate might be a considered a case of Substitute.
Update (currently Add)	StateChange, SurfaceChange, Decrease, Increase, ShapeChange	Update is a generalisation of StateChange, SurfaceChange, Decrease, Increase and ShapeChange.
Validate	Compare, Question	Validate is a combination of Compare and Question.

Many of the e-Framework Service Genres are specialisations of the SUMO concepts, suggesting that the latter are at a higher level of abstraction than the former, although there are some Service Genres that have exact equivalents and some that are generalisations. If the SUMO concepts were to be used as Service Genres in place of the existing Genres, the specific cases that are specialisations of a given SUMO concept would need to be listed in the Service Genre. For example, a Manage Service Genre would encompass the existing Authenticate, Authorise and Manage Members Service Genres.

There are some places in which the SUMO concepts are inadequate. For example, the Authenticate, Authorise and Comply Service Genres are all part of the management of user access, and do not fit well within the SUMO structure, except by mapping to very generic SUMO concepts. It is possible to extend SUMO in the case that additional core processes are required. This approach has an advantage over the current e-Framework approach in that it ensures that new processes are compatible with existing SUMO concepts, and publishes them for wider use.

5.3 Evaluation of the Use of SUMO for e-Framework Service Genres

There are many benefits in using a previously selected standard for the specification of Service Genres, and an upper level ontology of processes is an ideal candidate for this since it provides a formalised, considered and hopefully complete picture of possible processes. However, SUMO does not perfectly fit the notion of Service Genres as it has been proposed and developed by e-Framework practitioners. Table 2 (Section 5.2) shows that many of the SUMO concepts are more general than the e-Framework Service Genres, although some Service Genres combine more than one SUMO concept.

The selection and development of the original Service Genres in e-Framework (before this work) was driven by the requirements of Service Usage Models. Service Usage Models were developed to describe systems, dictating the need for Service Genres and Expressions as components within those Service Usage Models. This resulted in the development of Service Genres (often initially for a particular purpose) that were generalised when additional Service Usage Models were created. However, since e-Framework is in its early stages of development, this generalisation process has so far been limited in scope. It is therefore likely that over time, the e-Framework Service Genres, particularly if fully abstracted from their implementation, would become more similar to the SUMO concepts.

The set of SUMO concepts is thought to be sufficiently complete for the purposes of e-Framework. It has been developed over several years and is subject to addition and evolution to fill any gaps. There is a difference in focus in the sense that e-Framework describes processes in an information system, while SUMO describes generic processes, including human processes. Many of these human processes are concepts that reflect Service Genres, and may be used as such, but do not immediately obviously apply because they are specified under categories that would appear to be human-specific. Thus SUMO concepts are often available that fulfil the required purpose, but may be located in a position that seems counter-intuitive. For example, the 'Request' concept, which may be commonly required in information systems descriptions, is grouped under 'Linguistically Communicate', which in turn is grouped under 'Socially Interact'. Non-literal interpretations of SUMO concepts are required to apply it to e-Framework.

SUMO is considered a suitable candidate for a set of Service Genres for e-Framework, and would provide a conceptual and abstract basis for description of resources to proceed, as well as providing a way to relate human-readable e-Framework descriptions to machine-readable descriptions (for example, in web service ontologies).

6 USING E-FRAMEWORK WITH GEOSPATIAL WEB SERVICES

This Section shows how OGC web services may be represented with e-Framework with examples from the user scenarios for each of the different types of e-Framework artefacts and evaluates the work.

6.1 e-Framework Artefacts for OGC Web Services

The OGC web service specifications vary in their content, and therefore in the ways in which they are represented in e-Framework. Some of the specifications are represented directly as Service Expressions, while others are referenced by Service Expressions and represented as Standards. Other specifications are too general to be Service Expressions, and so a profile of the OGC standard is mapped to a Service Expression. Table 3 lists the OGC specifications (including some pending specifications and discussion papers) and shows how each can be represented in e-Framework. The Table also references some of the elements shown in Figure 1. The last few items in the Table are currently discussion papers and are not yet standards, but represent documents that may fit into the e-Framework artefact infrastructure.

Table 3: OGC Standards and their Representation in e-Framework

OGC Standard	Description	e-Framework Representation
Catalogue Services Specification (04-021r3)	A specification for an interface to a registry for SOA artefacts, including web services. The specification includes bindings for Z39.50, CORBA/IIOP and HTTP, the latter being referred to as CSW.	Service Expression, realising Service Genre Manage (Get, Search, Write, StateChange, Destroy are also relevant)
CSW profiles (ebRIM, ISO 19115/19119). (05-025r3; 04-038r2)	Profiles for CSW, specifying particular information models (CSW does not specify an information model).	Not specifically represented – the CSW Service Expression should describe the different possible information models from the profiles.
Coordinate Transformation Service Implementation Specification (01-009)	A specification for interfaces to services that perform transformations of coordinates.	Service Expression, realising Genre Calculate.
Filter Encoding Implementation	A specification that describes an XML encoding for filter expressions. This	Standard

Specification (04-095)	is used by many other OGC specifications to perform queries.	
Geographic Objects Implementation Specification (03-064r10)	A specification that describes a set of geographic object abstractions, including Java bindings for those objects.	Standard
Geography Markup Language Encoding Standard (07-036)	A language for describing geographic features, including their geometries and attributes.	Standard
Geospatial Extensible Access Control Markup Language (GeoXACML) (07-026r2)	A language for describing geospecific constraints on access rights, an extension to XACML.	Standard
GML in JPEG 2000 for Geographic Imagery Encoding Specification (05-047r3)	A specification describing how GML can be used in JPEG2000 images to represent geographic imagery.	Standard
Grid Coverage Service Implementation Specification (01-004)	A specification for an interface to web services that return geographic coverages (digital geographic information representing space-varying phenomena) in response to a query.	Service Expression, realising Service Genre Get.
KML (07-147r2)	A language for describing geographic objects and their display in a browser.	Standard
OpenLS (Location Service) (05-016)	A specification of an interface to a set of web services to allow the creation of location based applications.	OpenLS is too large to be a single service expression. Each web service in OpenLS would be a service expression.
Observations and Measurements (07-022r1)	A schema (information model) to describe observations and measurements. Includes both UML models and XML encoding.	Standard.
Sensor Alert Service (06-028r3)	A specification for an interface to an event notification service for sensors in which a client may register for and receive alert messages.	Service Expression, realising Service Genre Publish (Declare and Get may also be relevant).
Sensor Model Language (07-000)	A language to describe processes and processing components associated with measurement and post measurement transformation of observations from sensors.	Standard

Sensor Observation Service (06-009r6)	A specification for an interface to web services that manage deployed sensors and retrieve sensor data (specifically observation data).	Service Expression, realising Service Genre Get (Declare and Write are also relevant).
Sensor Planning Service Implementation Specification (07-014r3)	A specification for an interface to web services that allow a client to check the feasibility of a certain set of requests for data from sensors or actually submit such requests.	Service Expression, realising Service Genre Plan (ChangeStatus, Declare, Get and Process may also be relevant).
Implementation specification for Geographic Information - Simple Feature Access – Part 1: Common Architecture (06-103r3)	An information model for simple geometries.	Standard
Simple Features Implementation Specifications for CORBA, OLE/COM and SQL (99-054; 99-050; 06-104r3)	A schema and set of operations in the relevant language/structure to implement the simple feature model.	Standard
Styled Layer Descriptor Implementation Specification (02-070)	A language for describing styles for presentation of items on maps.	Standard
Styled Layer Descriptor Profile of WMS (05-078r4)	A profile of a language for describing styles for presentation of items on maps showing how the language can be used with the Web Map Service Implementation Specification.	Standard
Symbology Encoding Implementation Specification (05-077r4)	A language to describe map symbols and their encoding.	Standard
Transducer Markup Language (06-010r6)	A language to describe transducers, including their data, how it is generated and what they can measure.	Standard
Web Coverage Service Implementation	A specification for an interface to web services that return geographic coverages (digital geographic	Service Expression, realising Service Genre Get.

Specification (07-067r5)	information representing space-varying phenomena) in response to a query.	
Web Feature Service Implementation Specification (04-094)	A specification for an interface to web services that return geospatial features in response to a query. Also includes operations for Update, Delete and Insert.	Service Expression, realising Service Genres Get, Search, Destroy, ChangeState and Write.
Web Map Context Documents Implementation Specification (05-005)	A specification describing a document that provides relevant invocation and parameter information for a collection of related maps created by WMS – this is designed to carry information about map combinations.	Service Expression, realising Service Genre Publish.
Web Map Service Implementation Specification (06-042)	A specification for an interface to web services that returns maps in response to a request.	Service Expression, realising Service Genre Publish.
Web Processing Service Implementation Specification (05-007r4)	A specification for an interface to web services that provide any sort of GIS functionality, including calculations or modelling. The interface includes operations to describe and execute the process or function.	The Web Processing Service is very generic, and could do almost anything, so is thought unsuitable for a Service Expression. Particular profiles or implementations of the interface are better suited to be Service Expressions (for example, see the Geolinking Service).
Web Service Common Implementation Specification (06-121r3)	A specification describing the elements that are common to many of the OGC web services, including the format of the GetCapabilities operation that describes all of the web services, exceptions and various other items.	Service Expression, realising Service Genre Declare.
Geolinked Data Access Service (04-010r1)	A specification for an interface to a web service that provides attribute data in XML format ready to be geolinked (linked by some geographic feature identifier to a geometry) to another geographic data set.	Service Expression, realising Service Genre Get.
Geolinking Service (04-011r1)	A specification for an interface to web services that combines the attribute data from a Geolinked Data Access Service and geometry information	Service Expression, realising Service Genre Combine.

	from some other source (usually stored locally). This may then be channelled into a Web Map Service to produce a map. The Geolinking Service was implemented in the SEE-GEO project as a profile of a Web Processing Service, and though later version no longer take this approach, the current work describes the Geolinking Service in this context.	
Geo Video Web Service (05-115)	A specification for an interface to web services that return a video stream and/or related textual data (for example, GPS readings).	Service Expression, realising Service Genre Get.
Web 3D Service (05-019)	A specification for an interface to web services that return a 3D scene graph.	Service Expression, realising Service Genre Get.
Web Coverage Processing Service (06-035)	A specification for an interface to web services that process coverages (digital geographic information representing space-varying phenomena). Various transformations are offered. Web Coverage Processing Service is not currently a profile of Web Processing Service, but is likely to become one in the future.	Service Expression, realising Service Genre Calculate.
Web Image Classification Service (05-017)	A specification for an interface to web services that classify raster images (for example, land classification). Includes both retrieval of classifications and training of classifiers.	Service Expression, realising Service Genre Classify (Get, Calculate and Learn are also relevant).

The guidelines used for determination of the appropriate e-Framework artefact are that a Service Expression should represent a behaviour, process or operation that could normally be implemented as a web service (as shown in Figure 1). However, Service Expressions are intended to be sufficiently generic that they do not require regular editing. The OGC also publishes a number of abstract specifications to describe general principals that relate to geospatial information, and from which the specific specifications in Table 3 were developed. As can be seen Table 3, the majority of the OGC specifications are represented as Standards in the e-Framework infrastructure. The most common OGC specifications that are represented as Service Expressions are shown in Diagrammatic form in Figures 2 to 5. Figure 2 contains a UML diagram for the Catalogue Services Specification showing Service Expressions and Genres; Figure 3 contains the same information for the Web Feature Service

Specification; Figure 4 for the Web Map Service and Figure 5 for the Web Processing and Geolinking Services. Figure 3 also illustrates the case in which a Service Expression maps to several Service Genres, which is discussed in more detail below.

The Appendices contain example e-Framework artefacts to describe the user scenario. Appendix A contains the *Get* Service Genre. This is referenced by a number of Service Expressions, including the *Get Feature* Service Expression (see Figures 2 and 3). Appendix B contains the *Get Feature* Service Expression (corresponding to Figure 3). Finally, Appendix C contains the Service Usage Model for the Geolinking user scenario described in Section 4. While this work has addressed the best way for the representation of the OGC web services in e-Framework, it would also be possible to represent other geospatial processes (for example, those covered in the typology presented by Lemmens (2006) and discussed in Section 5.2). These would usually be represented as Service Expressions, as they are not sufficiently generic to be Service Genres.

Figure 2: Service Genre and Expression Diagram for OGC Catalogue Services Specification and Profiles

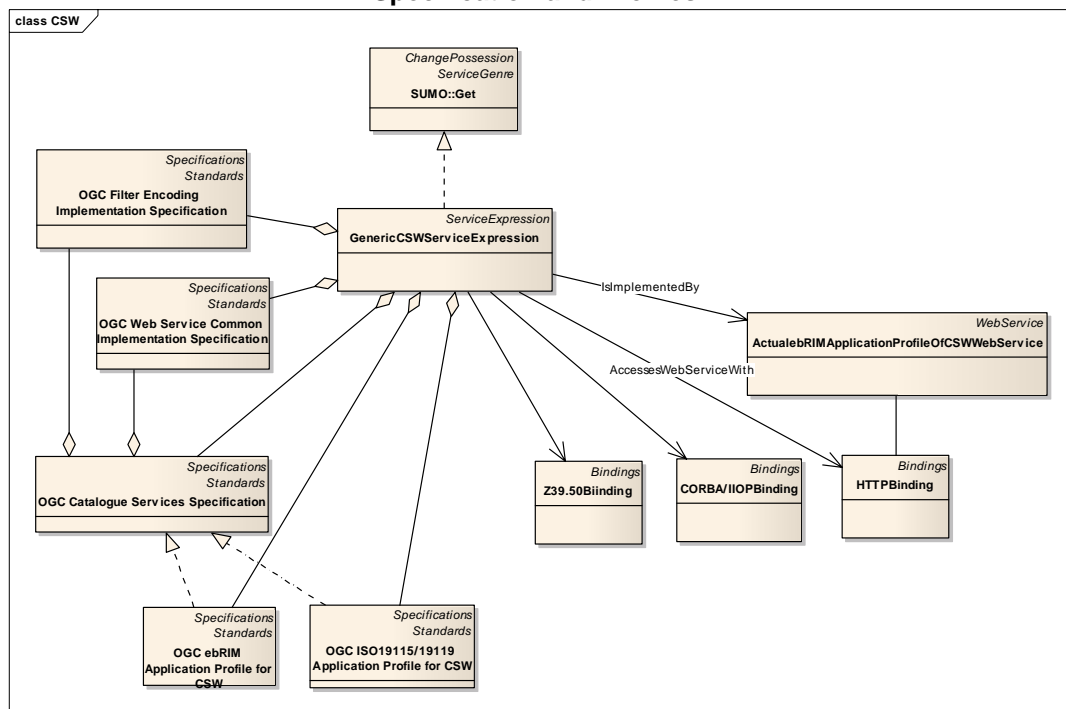


Figure 3: Service Genre and Expression Diagram for OGC Web Feature Service Specification and Profiles

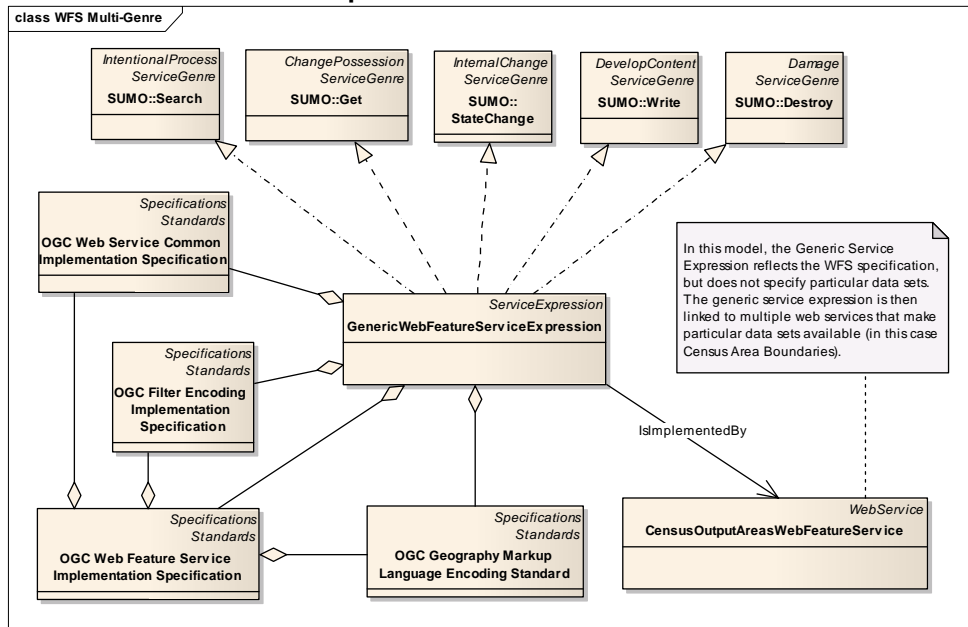


Figure 4: Service Genre and Expression Diagram for OGC Web Map Service Specification and Profiles

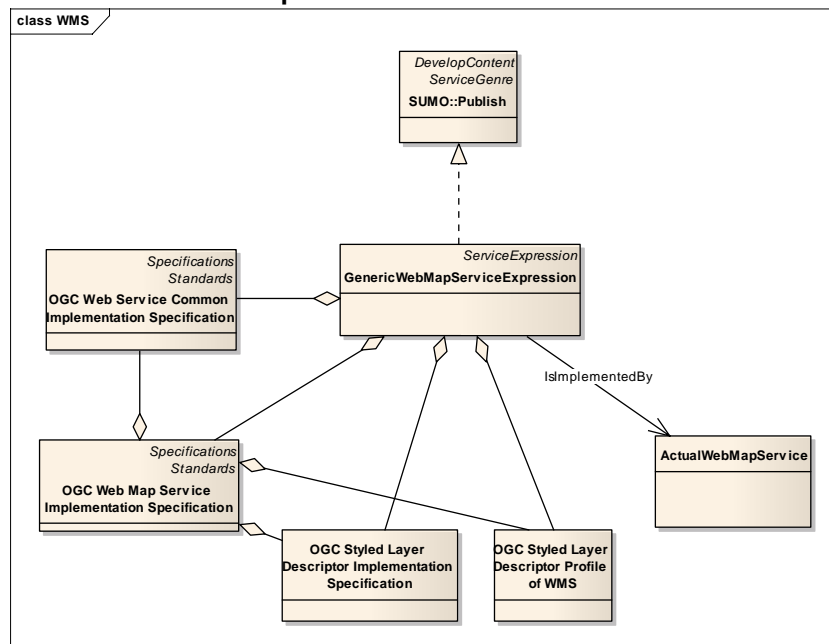
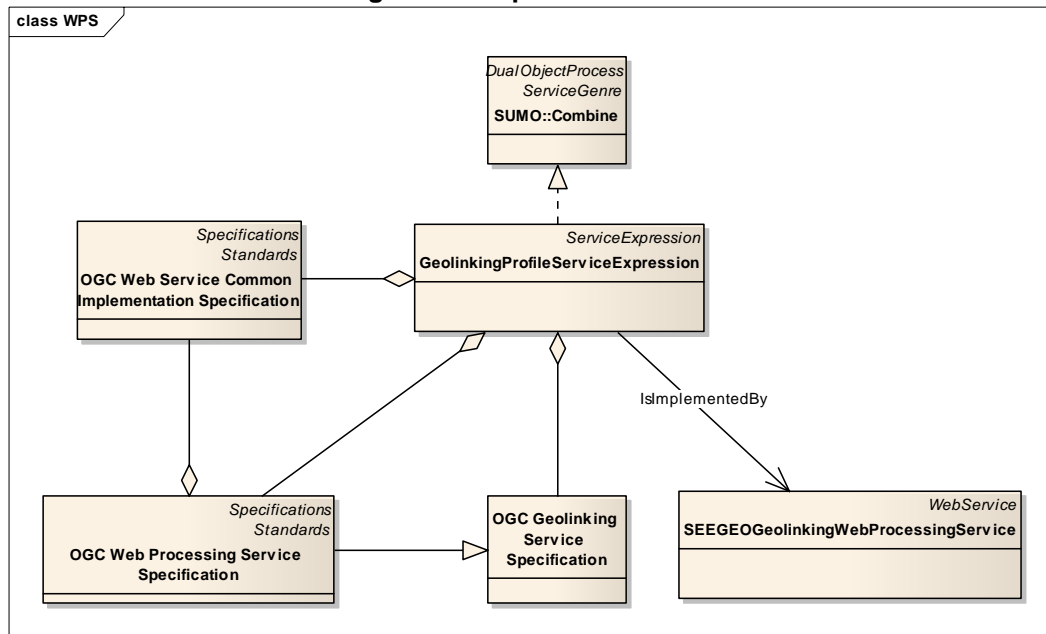


Figure 5: Service Genre and Expression Diagram for OGC Web Processing and Geolinking Service Specification and Profiles



6.2 Evaluation of the Application of e-Framework to Geospatial Web Services

In many cases, it was difficult to determine the relationship between the OGC-based Service Expressions and Service Genres due to the constraint that a Service Expression normally realises only one Service Genre. Many of the OGC standards describe web services or interfaces that are large and complex, often with a number of different operations, each performing different functions. It was therefore difficult to describe the OGC-based Service Expressions as realising only one Service Genre. In this work, a single Genre has been selected where possible, but in most cases this constraint means that the Genre does not fully reflect the scope of the Service Expression. For example, the Catalogue Services Specification contains operations for GetCapabilities, DescribeRecord, GetDomain, GetRecords, GetRecordById, Transaction (including Insert, Update and Delete) and Harvest. A number of Genres are needed to fully reflect all of this functionality, including Get, Search, Read, Write, Manage and StateChange. In this work, the Genre Manage was selected as the most important function, but this does not include the Transaction operation and does not reflect the management function of the Catalogue.

The expression of each operation of the OGC web services standards as a Service Expression was considered. However, this approach is not coherent with

the notion of an OGC standard-based web service as a coherent entity (the way they are used within the geospatial community), and obscures the position of the OGC standards within e-Framework. Furthermore, the OGC web service operations are often used in conjunction with each other to perform a particular function (for example, the common GetCapabilities function describes the capabilities of a web service, and the results returned are often used to automatically formulate a later request for the actual service), so cannot always easily be separated.

This issue is precipitated by the range of different levels of modularity in web services, from web services that perform very specific functions to those that perform a number of different functions (as per the OGC standard web services). The e-Framework artefact information model accommodates the former, but does not accommodate the latter. It is recommended that the constraint that a Service Expression can only realise one Service Genre be relaxed to overcome this issue. Table 2 includes both the main Service Genre that each Service Expression realises and the other Service Genres that may be important if this rule relaxation were to occur, and Figure 3 shows a Service Expression that realises multiple Genres (for the OGC Web Feature Service). At this early stage, this change would not adversely impact e-Framework development, but would make it more flexible for web services of different granularities. An alternative would be to refactor the OGC web service specifications, but since they have been in development for many years, this would be a much larger undertaking than simply relaxing the e-Framework constraints. Furthermore, the variation in granularity among different types of web services is well recognised in SOA circles (Erl, 2004), and a solution that limits this variation is not considered desirable.

7 DISCUSSION AND FUTURE WORK

e-Framework provides a useful model for describing artefacts in a Services Oriented Architecture. The detailed human-readable descriptions are especially comprehensive. The framework is broadly useful for describing geospatial artefacts, but would benefit from the removal of the constraint that a Service Expression can realise only one Service Genre, as this constraint does not accommodate web services that reflect a grouping of several functions, as are common in the geospatial domain.

The Service Genre definitions used in e-Framework would also benefit from the use a formally defined, standard approach to the definition of processes, as is included in SUMO.

Section 2 described the role of e-Framework as a human-readable set of artefacts for modularised functionality, and identified existing machine-readable

approaches to the same problem. Ultimately, both approaches are required to provide a coherent resource discovery and execution process, and future work is recommended to connect the e-Framework artefacts to one or more of the existing machine-readable approaches. This activity would involve further analysing both approaches to identify overlaps (furthering the work begun in Table 1), identifying the strengths of each approach, and creating a coherent information model to encompass both requirements, including e-Framework (possibly adapted to remove duplicated components) and a selected machine-readable approach.

8 CONCLUSIONS

The e-Framework infrastructure is a method for describing resources within a Services Oriented Architecture that is suitable for human assessment of those resources to determine whether they meet a required purpose. The work presented in this paper has provided an information model to describe the e-Framework descriptive infrastructure, and has also shown that the e-Framework descriptive infrastructure can be used to describe resources from the geospatial domain.

The process of using e-Framework to describe resources from the geospatial domain has highlighted firstly that the SUMO upper level ontology presents a set of processes that would be suitable for use as Service Genres in e-Framework; secondly that the existing e-Framework constraint that a Service Expression may only realise one Service Genre does not allow e-Framework to deal well with large and complex web services and that it would be better to relax this constraint and thirdly that future work to integrate e-Framework human-readable descriptions with existing machine-readable descriptions would be advisable.

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Appendix A: Get Service Genre

e-Framework Service Genre: GET

- Alternative name(s): Geospatial GET Service Genre

Rationale

The Geospatial GET service genre describes the process by which a client retrieves the requested information from a geospatial data resource. The geospatial data resource typically is managed by a geospatial web service which provides facilities for the discovery, access and administration of the geospatial information resource. Examples of such geospatial web services include, a Web Map Service, a Web Feature Service, a Metadata Catalogue Service, etc. The GET service interface of such geospatial web services enables a mechanism for the external client (requestor) to interact with the geospatial data resource to obtain requested information.

A Geospatial GET service MAY employ a simple request-respond model and provide read-only access to a geospatial information resource, ie, non-transactional, and clients may not update or remove data objects within the data resource. A Geospatial GET service is expected to be used in conjunction with a discovery service, such as query or search. The objects to be retrieved by the GET service must first be discovered. Clients that access a geospatial web service typically have a-priori knowledge of the application schemas used in that domain.

This document is a general description of a Geospatial GET service genre, independent of geospatial application end points, resource, data object, or underlying communications protocols and service models. The GET service genre does not include additional functionality, such as authorisation and discovery. Those facilities MAY be described in other service genres respectively, or included as part of a service usage model that combines these functions with GET.

The words MUST, MUST NOT, REQUIRED, SHALL, SHALL NOT, SHOULD, SHOULD NOT, RECOMMENDED, MAY, and OPTIONAL in this document are to be interpreted as described in [RFC 2119].

Service Genre Definition

Classification^{12,13,14}

To be provided by the submitter:				
Domain(s)	<input type="checkbox"/> Learning & Teaching	<input type="checkbox"/> Research	<input type="checkbox"/> Administration	<input checked="" type="checkbox"/> Common
		<input type="checkbox"/> Libraries	<input type="checkbox"/> IT Services	
Maturity	<input checked="" type="checkbox"/> Immature	<input type="checkbox"/> Mature		
Deployment Scale	<input type="checkbox"/> Isolated	<input checked="" type="checkbox"/> Ubiquitous		

¹² Classification categories shown in **Bold** are required.

¹³ Optional classification category "Deployment Scale" can be deleted from the table if not used.

¹⁴ See definitions of the Service Genre Classification Scheme categories and their allowable choices

at :

<http://www.e-framework.org/Services/ServiceClassificationScheme/ClassificationSchemeForServiceGenres/tabid/814/Default.aspx>

To be determined by the e-Framework:			
Status	<input type="checkbox"/> Approved	<input type="checkbox"/> Placeholder <input checked="" type="checkbox"/> Unapproved	<input type="checkbox"/> Superseded <input type="checkbox"/> Withdrawn
Confidence Level	<input type="checkbox"/> High	<input checked="" type="checkbox"/> Medium	<input type="checkbox"/> Low

Version

- e-Framework Service Genre Version: v1.0

Version History

Version	Date	Author	Description	Organization / Project
v0	15/10/2008	Yin Chen	Initial Draft	EDINA
v1.0	27/02/09	Chris Higgins	Minor edits	EDINA

Description

The Geospatial GET service genre provides the mechanism to retrieve information from geospatial data repositories, making them available to external applications and end users.

Many geospatial data sources (collections, repositories) wrapped by geospatial web service expose a GET interface. Clients MAY send requests to this interface to retrieve the objects stored or managed by the data source. The associated geospatial web service will respond to the request with the requested set of objects out of those managed by the data source. Typically, the data retrieved will be one or more of the objects in a repository. If there are multiple representations or formats of the object available from the repository, any of these MAY be requested. The geospatial web service determines what object representation (if any) to return in response to the GET request. The details of the data model, formatting and encoding used to return results sets to the client are defined in the service expressions that specialize this service genre.

The GET service genre MAY be access controlled. A client request MAY include necessary authorization and authentication credentials such that the Geospatial GET service MAY permit or deny access to the requested objects. The source of the authorization and authentication credentials is not defined by this service genre. The geospatial service for the data source is responsible for determining what results it will return, by applying filtering to responses according to authorization-based access control constraints.

The Geospatial GET service genre MAY be specialized in a service expression to:

- Get particular types of object representations and formats
- Specify data encoding and exchange format for the objects returned
- Specify communication protocols.

Functionality

The Geospatial GET service genre supports simple functionalities to obtain objects from the geospatial data source.

A request SHALL specify:

- What objects to retrieve.[REQUESTED]
- What operation to use.[REQUESTED]
- The requested parameters.[REQUESTED]

A request MAY specify:

- What representation of the objects to present to the requestor (i.e., which representations or format to return).[OPTIONAL]
 - Representations SHOULD refer to existing standards and SHOULD include version numbers or version information.
- How to encode results [OPTIONAL].
 - Encoding SHOULD refer to existing standards and SHOULD include version numbers or version information.

No other functionality is defined. The functionality that is defined MAY be extended. Major new or additional functionality SHOULD NOT be included; extended capabilities SHOULD be included in other service genres.

Usage Scenarios [optional]

Scenario A: Get Service Capabilities

- A requestor accesses a geospatial web service to find out what operations the server exposes;
- The geospatial web service returns a capabilities document in the XML format, describing the operations, functionality, and features made available by the service;
- The requestor downloads and displays the XML documents via the web browser.

Scenario B: Get Map

- A requestor specifies the geographic area to be displayed, the layers which the map is composed of and how each layer should be rendered in the image through a standardised interface defined by the OGC Web Map Service specification;
- The OGC Web Map Server retrieves a dynamically generated map image and delivers to the requestor;
- The requestor displays the map image on a standard HTTP web browser.

Scenario C: Get Features

- A requestor accesses a OGC Web Feature Service by passing the URL of the feature server into the address box of a web browser along with CGI style parameters that indicates which feature types (e.g. "bridge", "river", "police district") to retrieve.
- The OGC Web Feature Server returns the list of feature instance for requested feature type.
- The requestor downloads and displays the results via the web browser.

Applicability [optional]

The service genre is applicable for retrieving any defined geospatial data representation or format for any specific geospatial data object(s) managed by the geospatial web service. Use of a Geospatial GET service interface presupposes that the requestor and the service provider have a common understanding of the retrieved information.

The Geospatial GET service genre does not provide a mechanism for search. Retrieval is accomplished by identifier-match, that is, only the uniqueness of the identifier which refers the locators in the geospatial data resource is relevant to the Geospatial GET service genre.

The Geospatial GET service genre does not provide a mechanism for access control. A Geospatial GET service MAY be used in conjunction with access control methods to control the return and filtering of results.

Requests & Behaviours **[recommended]**

The formats and definitions for requests and responses SHALL be defined by the service expressions that specialise the service genre. Requests and behaviours SHALL meet the following conditions:

- GET Request SHALL be defined:
 - The request SHALL be capable of retrieving a single object given its name or identifier.
 - The request MAY be capable of retrieving a set of objects given a set of names or identifiers. Each name identifies a single object to be retrieved.
 - The request MAY permit the client to specify the data encoding or output format for the requested objects. The same output format or encoding SHALL be returned for all objects.
 - The request MAY permit the client to specify one or more acceptable representations for the requested objects. The same representation SHALL be returned for all objects.
 - The request MAY specify contextual information, to allow the service genre to determine which object instance and/or representation should be retrieved.
- GET Responses SHALL include error indicators or other needed control information.

Use & Interactions **[recommended]**

The model and the implementation protocol for a client to interact with a Geospatial GET service SHALL be defined by the service expression that specialise the Geospatial GET service genre.

Structure **[optional]**

The GET service genre assumes the following logical data model for accessed and retrieved geospatial data objects:

- Objects are within collections in a managed data source. The physical manifestation of storage of the objects is hidden behind the service interface.
- Each object has a unique identifier. Identifier or access keys are attributes of an object, that distinguishes an object from all the other objects held in the data source.
- Each object MAY have one or more digital representations. Different representations MAY be stored as static objects or they MAY be generated from the same underlying object on the fly in response to a request.

- A GET request for an object is a request for an object or objects to be transmitted to the requestor from the data source. The requested object representation and encoding is considered an object to be returned to the client.
 - The objects SHALL be encoded according to the request, which MAY be specified by the requestor or a default encoding MAY be returned if not specified.
 - The representation or output format returned MAY be specified by the requestor or a default representation MAY be returned if not specified.
- Additional encodings MAY be required to support transport-level message exchange.

The structure of the service genre SHALL be defined by the service expressions that specialises the service genre.

Applicable Standards [optional]

No standards are directly applicable to the service genre as a whole.

The service expressions that specializes the service genre SHALL be defined in terms of standards:

- Service expressions SHALL specify applicable digital representation standards, data encoding and formats for the data objects.
- Service expressions SHALL specify applicable communications, encoding and transport protocols.

Design Decisions & Tradeoffs [optional]

<type text here>

Implementation Guidance & Dependencies [optional]

Consistency:

- The service implementation SHALL ensure that all data objects and all representations managed by the data source are obtainable.
- The service implementation SHOULD ensure that all clients get the same version of data (e.g. the latest updates) they request.

Performance:

- A service implementation SHALL be capable of handling simultaneous requests from different clients.
- A service implementation SHOULD optimise the data retrieval at the expense of data creation and maintenance.
- Load balancing SHOULD be implemented for large resources or those that are accessed frequently (continuously).

- Flow control SHALL be implemented in contexts where returned representations are sizeable, or when large sets of objects are retrieved. Large results sets MAY be broken up over multiple request-response pairs.

Security and Privacy Considerations:

- Service implementations MAY be subject to denial-of-service attacks.
- Care should be taken to maintain privacy of any personal data or other records that MAY disclose usage patterns.
- The client should not be able to discern existence of access-controlled objects by examining error codes.

Known Uses [optional]

<type text here>

Related Service Usage Models (SUMs) [optional]

<type text here>

Related CORE SUMs [optional]

<type text here>

Appendix B: Get Feature Service Expression

Service Expression Name: GET FEATURE

Classification:

Geospatial

Service genre:

GET

Description:

This service expression is a specialization of the *GET* service genre. It enables a client to retrieve information from a database of data items called features held in a feature server. Typically features are geo-referenced, that is tagged with spatial information such as co-ordinates and geometries. This means that data features can be filtered using a spatial query, for example, to retrieve features located within a specified area, list all features crossing another feature and so on. While spatial data is the norm, features do not have to be geo-referenced and non-spatial queries can also be employed to retrieve feature data from the server, for example, listing all features of type “river” (regardless of location).

This expression of the *GET* genre uses the OGC Web Feature Service [WFS] specification [1] for querying and retrieving spatial and non-spatial datasets. The expression narrows the WFS specification to a subset of operations and configuration options that constitute the minimal functionality that the specification mandates, and is referred to in the specification as “Basic WFS”. Specifically, the service expression describes a read only WFS implementation. Clients are able to discover the service operations and feature types made available by the service and also filter parts of the available dataset using both spatial and non spatial constraints. This expression does not permit a client to access the feature server to update or delete features, obtain locks on data or submit queries that traverse feature hierarchies using theW3C XML Linking (XLINK) mechanism [11].

In compliance with WFS, communication is based on the HTTP [8] protocol with both the HTTP GET and HTTP POST methods available to clients for requesting spatially encoded information. Query parameters are encoded either with XML for HTTP POST requests or the CGI [13] style keyword-value pairs for HTTP GET requests. The scope of this service expression does not include SOAP encoding of messages, an optional configuration in WFS. Query results are encoded in XML using the Geography Markup Language [GML] [2].

Functionality:

The *GET FEATURES* service expression provides read only access to a web feature server – the operations to support this are:

GetCapabilities: Describe the capabilities of the feature server.

Specifically, indicates which feature types (e.g. “bridge”, “river”, “police district”) are available and what operations are supported on each feature type. This operation returns a capabilities document conforming to the schema described in the WFS specification.

DescribeFeatureType: Describe the structure and properties of a given feature type.

GetFeature: Queries feature server to retrieve one or more feature instances. The client can specify which feature properties to fetch and is able to constrain the query spatially and non-spatially.

The WFS specification defines a schema for describing the capabilities of the feature server. To implement the *GET FEATURES* service expression the service administrator **MUST** provide a valid capabilities document that restricts the available operation to just the three above. The following optional WFS operations **MUST** be omitted from the capabilities document:

GetFeatureWithLock
GetGmlObject
Transaction
LockFeature

The WFS specification provides a mechanism to restrict what kind of operations can be applied to individual feature types, so it is possible to configure the feature server to allow a client to create new instances of the “bridge” type, but prohibit the creation of feature instances of type “river”. As this service expression only permits a client to execute queries, the service administrator **SHOULD** specify only the <QUERY> sub element on all feature types in the capabilities document. The following sub elements **SHOULD** not be applied to any feature type in the capabilities document.

<INSERT>,
<Update>
<Delete>
<Lock>

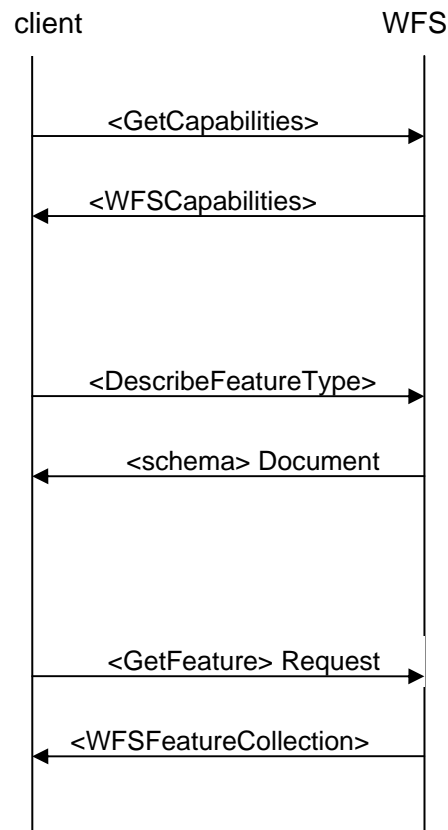
Usage scenarios:

This service expression provides a mechanism for a requestor to execute queries on a dataset through a standard interface. The main use case is executing spatial data queries. Any HTTP [8] client can access the service. A requestor can access the service with a standard web browser by pasting the URL of the feature server into the address box along with CGI style parameters that define the operation to execute and any additional qualifiers of the query. If the query is valid, an XML document is returned and can be viewed or downloaded via the browser. This access is only useful for testing. A more typical way to access the service is with specialized Geographic Information System [GIS] software that helps the requestor formulate a query by clicking on maps and selecting features and properties from dropdown lists rather than typing in a verbose URL string. Similarly client software will display results on dynamically generated maps rather than XML.

Often an end user's client does not communicate directly with the feature service at all, but instead speaks to an intermediary server process that will initiate several requests to one or more feature servers, as well as other data providers, typically aggregating the responses before displaying the result to the end user. For example, crime statistics could be aggregated with police district boundary data to show which police forces are most successful in tackling certain crimes. Standard based tools exist that make it easy for non-programmers to create and publish such aggregations.

The typical usage scenario for the *GET FEATURES* service expression involves two phases, a discovery phase and a query phase. In the discovery phase the client queries the WFS server using the *GetCapabilities* operation to find out what operations the server exposes and which feature types are available. The server returns a WFS capabilities document that lists the operations, feature types and predicates that can be applied when making queries. The client may find out more information about a particular feature type by invoking subsequent *DescribeFeatureType* operation for individual features listed in the capabilities document. Once the client has gathered enough information about the WFS server's capabilities the query phase can begin by the client calling the *getFeature* operation. This operation returns a collection of features encoded in Geography Markup Language (GML) [2]. The client can apply multiple filters to the *getFeature*

operation to constrain the result set using both spatial predicates (e.g. “within”, “contains” , “overlaps”) and non spatial predicates (e.g. “equalsExact”, “lessThan”, “greaterThan”).



Applicability:

The service expression does not apply to a service provider that requires authentication or limits the filters than can be applied to a WFS query using security policies / standards. Similarly, charging fees for retrieval of data is not applicable to this service expression. Queries to multiple servers are also out of scope. The expression requires a WFS implementation reside on a single server instance that exposes a read only interface to clients. Performing transactions on the dataset such as deleting, updating and obtaining locks on data is not in scope for this service expression. The use of W3C XLinking [11] for traversing hierarchical structures is also excluded from this service expression.

Requests And Behaviours:

The format for request and response is as defined in the WFS specification. Three service operations are supported as enumerated in Functionality. This service expression does not apply any additional requirements on the construction of requests. The service expression prohibits the following optional parameters on the *getFeature* operation:

EXPIRY
TRAVERSELINKDEPTH
TRAVERSELINKEXPIRY
PROPTRAVXLINKDEPTH
PROPTRAVXLINKEXPIRY

Use and Interactions

The service expression involves two agents; a requestor and a responder. The requestor initiates a request by sending an HTTP message to the server using either GET or POST operation. The server will respond with a valid result or an exception message in conformance to the WFS specification. Response objects SHOULD be accompanied by HTTP Expires and Last-Modified headers to provide information the requestor can use for caching. Similarly, the Content-Length header SHOULD be provided so that the requestor can determine when data transmission is complete and allocate space for results. The Content-Encoding or Content-Transfer-Encoding headers SHOULD also be provided in the response message so the requestor can decide the best way to display the results.

Structure

Feature definitions in the dataset of the *GET FEATURES* service expression are based on GML [2]. GML does not itself provided the schema for features but specifies abstract data types that should be extended and rules that should be followed when modelling a feature. Data modellers will need to extend the framework provided by the GML feature schema to create actual feature instances for a particular WFS server instance. The principle restrictions on how the model can be constructed are:

1. Feature geometry must be expressed using the GML geometry description. (gml.xsd).
2. Spatial Reference Systems must be expressed as defined in the OpenGIS Geography Markup Language (GML) Implementation Specification, version 3.1 [2].
3. Elements nested immediately below the root element of a feature type define properties of that feature.

For example, the following example shows a feature instance for a bridge type in the user defined schema:

```
<app:Bridge gml:id="...">
  <app:span>400</app:span>
  <app:height>50</app:height>
  <gml:centerOf>
    <gml:Point gml:id="P1" srsName=".." />
  </gml:centerOf>
</app:Bridge>
```

Elements defined within the “app” namespace (e.g. <Bridge>, <height>,) here are entirely within the discretion of the model creator for a particular WFS. The “centerOf” property is part of the GML namespace as this is a geometry property. Each child element of the <Bridge> root element is interpreted as a property of the feature. It is not permitted to have another feature as a child element of <Bridge> as the server would incorrectly interpret the element as feature property rather than a feature type.

The <Bridge> element is inherited from the GML <AbstractFeatureType>. Extending this type, while not required, facilitates compliance with GML features and enables reuse of data components, for example, the “gml:id” attribute used as feature identifier type in the <Bridge> element. A possible schema for the feature instance above then might be:

```
<element name="Bridge" type="app:BridgeType" substitutionGroup="gml:_Feature"/>

<complexType name="BridgeType">
  <complexContent>
    <extension base="gml:AbstractFeatureType">
      <sequence>
        <element name="span" type=".."/>
        <element name="height" type="..."/>
        <element ref="gml:centerOf"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
```

Different communities have established their own GML application profiles that provide a standard vocabulary of features pertinent to their discipline. Examples include the [Aeronautical Information Exchange Model \(AIXM-GML\)](#), the [Climate Science Modelling Language \(CSML\)](#), [GeoSciML - Geological Sciences ML](#) and [CityGML](#). A full listing of profiles can be found at:

<http://www.ogcnetwork.net/node/210>

Interface definition

Requests to a *GET FEATURES* implementation MUST be sent using the HTTP protocol using either the POST or GET method. The requestor SHOULD encode the request using GET along with Key Value Pair [KVP] syntax for simple requests. This style of request is the most familiar for those working in the geospatial community and adheres to principles of the REST [?] architectural style, making the read only semantics of the *GET FEATURES* service expression explicit in the transport protocol. For more complex queries the KVP notation is likely to be cryptic and difficult to work with, so the requestor MAY prefer the alternative XML encoding (<http://schemas.opengis.net/wfs/1.0.0/WFS-basic.xsd>) of the request which MUST be sent using the HTTP POST method. The WFS interface part (e.g. *getFeature* operation) of the XML encoded request MUST be identified using the namespace <http://www.opengeospatial.net/wfs>. For encoding the query condition (e.g. *featureId*) the “ogc” filter vocabulary should be used with the namespace <http://www.opengeospatial.net/ogc>. An example request using the XML encoding is shown below:

```
<GetFeature version="1.0.0" service="WFS" xmlns="http://www.opengis.net/wfs"
xmlns:ogc="http://www.opengis.net/ogc" xmlns:xsi="http://www.w3.org/2001/XMLSchema-Instance">
```

```
xsi:schemaLocation="http://schemas.opengis.net/wfs/1.0.0/WFS-basic.xsd">
  <Query typeName="BRIDGE">
    <ogc:Filter>
      <ogc:FeatureId fid="BRIDGE.1001"/>
    </ogc:Filter>
  </Query>
</GetFeature>
```

The KVP equivalent of the above request is:

<http://www.someserver.com/servlet/wfs?request=GetFeature&FEATUREID=BRIDGE.1001>

This service expression does not describe how a WFS request can be bound to a SOAP message format. Although this is described in the WFS specification, in practise SOAP is not used widely in the geospatial community for constructing WFS requests and is omitted from this service expression.

When the *GET FEATURES* responder agent has processed the request, it will generate a status report and hand it back to the requestor. If an error occurs the responder will generate an XML status report and hand it back to the requestor. The exception message is wrapped in a *<ServiceExceptionReport>* element as defined in the OGC Exception schema (<http://schemas.opengis.net/wfs/1.0.0/OGC-exception.xsd>). If the *getFeature* request is successful the responder will generate a status report with a root element *<FeatureCollection>* conforming to WFS interface schema (<http://schemas.opengis.net/wfs/1.0.0/WFS-basic.xsd>). Features themselves are specified using the GML, in conjunction with WFS interface components as described in "Structure" section of this service expression. The response to *getCapabilities* and *describeFeatureType* operations returns an XML document conforming to WFS Capabilities schema (<http://www.opengis.net/wfs>)

Design Decisions And Tradeoffs

Consistency:

A *GET FEATURES* responder implementation does not have to ensure that all clients get the latest updates to features they request. A performance trade off is accepted that allows caching of results both on client and server. The service expression does permit locks on features and therefore the requestor should never be blocked from obtaining results when updates occur.

Performance:

The *GET FEATURES* service expression has read only semantics and therefore the database and server should be optimised for data retrieval at the expense of data insertion or updates. The service implementation should employ caching to improve performance and scalability. This may mean users sometimes do not have the latest updates available.

A restriction such as *DefaultMaxFeatures* should be placed on the size of result set for any particular query to ensure an insufficiently specified request does not cause blocking of other requests by returning massive result sets. If there is demand for certain large datasets the *GET FEATURES* responder agent SHOULD provide a separate download facility that bypasses the WFS server and executes a bespoke query on the database using an optimized view or pre-compiled archive.

Interoperability:

A service implementation should follow the WFS specification and related standards such as GML and OGC filter specification to ensure the services can work with all other WFS compliant clients and servers.

Security:

A service implementation SHALL inspect all requests for possible code injection.
A requestor SHOULD validate all XML results against appropriate schemas. (e.g. WFS interface schema , GML schema)

Related Standards:

- [1] Vretanos, Panagiotis (ed.), "Web Feature Service Implementation Specification V1.1.0" , Open Geospatial Consortium Inc.
- [2] Cox S., Daisey P., Lake, R., Portele C., Whiteside A. (eds.), "OpenGIS Implementation Specification #02-023r4: OpenGIS Geography Markup Language (GML) Implementation Specification, version 3.1.1", January 2005
- [3] Vretanos, Panagiotis (ed.), "OpenGIS Implementation Specification #04-095: Filter Encoding Implementation Specification", Dec 2004
- [4] Bray, Paoli, Sperberg-McQueen, eds., "Extensible Markup Language (XML) 1.0", 2nd edition, October 2000, W3C Recommendation, <http://www.w3.org/TR/2000/REC-xml>.
- [5] Beech, David, Maloney, Murry, Mendelson, Noah, Thompson, Harry S., "XML Schema Part 1: Structures", May 2001, W3C Recommendation, <http://www.w3c.org/TR/xmlschema-1>.
- [6] Bray, Hollander, Layman, eds., "Namespaces In XML", January 1999, W3C Recommendation, <http://www.w3.org/TR/2000/REC-xml-names>.
- [7] Clark, James, DeRose, Steve, "XML Path Language (XPath), Version 1.0", November 1999, W3C Recommendation, <http://www.w3c.org/TR/XPath>.
- [8] Fielding et. al., "Hypertext Transfer Protocol – HTTP/1.1," IETF RFC 2616, June 1999, <http://www.ietf.org/rfc/rfc2616.txt>.
- [9] Berners-Lee, T., Fielding, N., and Masinter, L., "Uniform Resource Identifiers (URI): Generic Syntax", IETF RFC 2396, <http://www.ietf.org/rfc/rfc2396.txt>.
- [10] Freed, N. and Borenstein N., "Multipurpose Internet Mail Extensions (MIME) Part One: Format of Internet Message Bodies", IETF RFC 2045, November 1996, <http://www.ietf.org/rfc/rfc2045.txt>.
- [11] Steve DeRose, Eve Maler, David Orchard "XML Linking Language (XLink) Version 1.0" W3C Recommendation 27 June 2001, <http://www.w3.org/TR/xlink/>
- [12] Whiteside, Arliss (ed.), "OWS Common Implementation Specification, V0.3.0", Open Geospatial Consortium Inc. document 04-016r3
- [13] CGI, The Common Gateway Interface, National Center for Supercomputing Applications, <http://hoohoo.ncsa.uiuc.edu/cgi/>

Appendix C: Geolinking Service Usage Model

e-Framework Service Usage Model Name

Geolinking

Version

Version 2.0

Version History

Include requested information about all versions of this document.

Version	Date	Author	Description	Organization / Project
v1.0	13/10/08	Chris Higgins	Initial Draft	EDINA, Univ Edinburgh
v1.1	3/11/08	Yin Chen	Additions	EDINA, Univ Edinburgh
v1.2	10/11/08	Chris Higgins	Check for consistency before sending for review	EDINA, Univ Edinburgh
v2.0	25/02/09	Chris Higgins	Following input and discussion with Phil Nicholls	EDINA, Univ Edinburgh

Rationale

The Geolinking SUM is a description of the collection of processes used to link attributes to core geospatial datasets at run time. The SUM is applicable within the geospatial domain and focuses on linking census statistics to census geographies. It has been created in association with the Secure Access to Geospatial Web Services (SEEGEO) project and supports an application implemented as part of this project.

The problem addressed is that core or framework Spatial Data Infrastructure (SDI) geospatial datasets such as census geographies have a potentially large number of different attributes that can be linked to them. Using standards based service components to separate the geospatial datasets from the attributes and link at run time increases efficiency, avoids duplication, and opens new possibilities for data integration.

The Geolinking service usage model may be used to:

- Illustrate how census statistics may be linked to census geographies at run time using open geospatial interoperability standards
- Illustrate how a wide variety of different attributes may be linked to a wide variety of framework geographies at run time using open geospatial interoperability standards
- Identify and document a key collection of service components reusable in a wide variety of Spatial Data Infrastructure scenarios
- Design, implement and deploy different geolinking applications and client systems using the defined services
- Provide an exemplar for discussion on how to promulgate geospatial service components in the academic sector

As geospatial information is ubiquitous and SDIs operate across sectors and disciplines, the SUM is applicable multiple areas relevant to the research and education community.

Classification¹⁵

Type an “X” in the brackets next to the most appropriate choice for each category. Required categories are shown in **Bold**; any non-required categories that are not used may be deleted.

To be provided by the submitter:			
SUM Type	<input checked="" type="checkbox"/> Domain	<input type="checkbox"/> CORE (a commonly recurring SUM; designation requires e-Framework Integrity Group approval)	
Domain(s)	<input type="checkbox"/> Learning & Teaching	<input type="checkbox"/> Research Libraries	<input type="checkbox"/> Administration <input type="checkbox"/> IT Services <input checked="" type="checkbox"/> Common
Maturity	<input checked="" type="checkbox"/> Immature	<input type="checkbox"/> Mature	
Purpose(s)	<input checked="" type="checkbox"/> Exemplar	<input checked="" type="checkbox"/> Application	<input type="checkbox"/> Modelling <input checked="" type="checkbox"/> Toolkit
XOR (exclusive “or”)	<input type="checkbox"/> Service Genres	<input checked="" type="checkbox"/> Service Expressions	
Development Status	<input type="checkbox"/> Proposed	<input type="checkbox"/> Developmental	<input type="checkbox"/> Prototype <input type="checkbox"/> Production
Deployment Scale	<input checked="" type="checkbox"/> Isolated	<input type="checkbox"/> Ubiquitous	
State Behaviour	<input type="checkbox"/> Stateful	<input checked="" type="checkbox"/> Stateless	
Transactional Behaviour	<input type="checkbox"/> Transactional and ACID	<input type="checkbox"/> Transactional but Non ACID	<input type="checkbox"/> Non-Transactional
Batch Behaviour(s)	<input type="checkbox"/> Individual	<input type="checkbox"/> Batch	
Time-Constraint Behaviour	<input checked="" type="checkbox"/> Hard Real Time	<input type="checkbox"/> Soft Real Time	<input type="checkbox"/> None
Service End Point	<input type="checkbox"/> Provider	<input type="checkbox"/> Requestor	<input checked="" type="checkbox"/> Transcoder (both requests and provides)
Authentication/ Authorization Dependency	<input type="checkbox"/> Auth-Dependent	<input type="checkbox"/> Auth-Independent	
Protocol Binding(s) (only applies to service expression-based SUMs)	<input type="checkbox"/> Web Service <input type="checkbox"/> SOAP	<input type="checkbox"/> REST <input checked="" type="checkbox"/> HTTP	<input type="checkbox"/> Other
To be determined by the e-Framework:			
Status	<input type="checkbox"/> Approved	<input type="checkbox"/> Placeholder <input type="checkbox"/> Unapproved	<input type="checkbox"/> Superseded <input type="checkbox"/> Withdrawn
Confidence Level	<input type="checkbox"/> High	<input type="checkbox"/> Medium	<input type="checkbox"/> Low

¹⁵ See definitions of the Service Usage Model Classification Scheme categories and their allowable choices at: <http://www.e-framework.org/Services/ServiceClassificationScheme/ClassificationSchemeForSUMs/tabid/817/Default.aspx>

Notation [optional]

Spatial Data Infrastructure (SDI): SDI encompasses the policies, organisational remits, data, technologies, standard delivery mechanism and financial and human resources necessary to ensure that those working with spatial data, whether at the global or local scale, are not impeded in meeting their objectives (INSPIRE consultation paper, 2003).

Framework dataset: Basic geographic data incorporating the most common data themes that geographic data users need, as well as an environment to support the development and use of those data. The framework's key aspects are: specific layers of digital geographic data with content specifications procedures, technology, and guidelines that provide for integration, sharing, and use of these data; and institutional relationships and business practices that encourage the maintenance and use of data. The framework represents a foundation on which organisations can build by adding their own detail and compiling other data sets (GSDI Cookbook, 2004).

Open Geospatial Consortium (OGC): Along with ISO TC/211, these are the two main open geospatial interoperability standards defining organisations.

Description

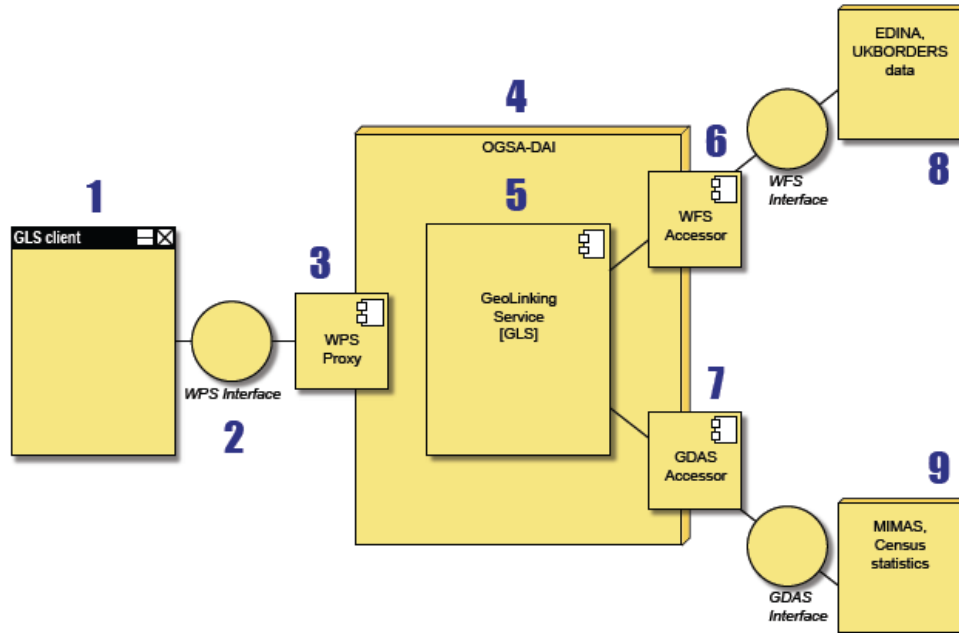
This SUM describes the processes used in a wide variety of SDI scenarios where the functionality is required to be able to link attributes to framework geospatial datasets at run time. It does so by reference to a Geolinking application supported by the SUM and created under the auspices of the SEE-GEO project.

The problem addressed by the SUM is that core or framework SDI geospatial datasets such as census geographies, eg, census output areas, enumeration districts, datazones, have a potentially huge number of different attributes that can be linked to them, eg, population, long term unemployed, number of schools. Currently, the most common practice is to hold copies of the data locally and process as required in accordance with the particular business requirements. This results in numerous problems, eg, uncertainty over multiple copies of the data held in different formats, with different versions, in different places, etc.

Using standards based data access and processing service components to separate the geospatial datasets from the attributes and link at run time increases efficiency, maintains currency of the data and metadata, avoids duplication, and opens new possibilities for data integration.

Figure 1 provides a deployment view on the Geolinking application implemented as part of the JISC funded SEE-GEO project.

Figure 1. High Level Architecture – SEE-GEO e-Social Science Demonstrator



The following narrative explains the SUMs intended function using the SEE-GEO application as an exemplar.

- The **Geo Linking Service (GLS) client** is a typical client used to create custom maps showing the distribution of a wide variety of health related statistics.
- The OGC Web Processing Service (**WPS**) **interface** provides a generic mechanism to describe and web-enable a wide variety of geospatial processes. In this case, the process is linking geospatial features to attributes at run time.
- The **WPS Proxy** allows the Grid middleware OGSA-DAI (Open Grid Standard Architecture – Data Access and Integration) to be used as a generic toolkit for building OGC compliant WPS.
- **OGSA-DAI** is a middleware product which supports the exposure of data resources, such as relational or XML databases, on to grids. Various interfaces are provided and many popular database management systems are supported. The software also includes a collection of components for querying, transforming and delivering data in different ways, and a simple toolkit for developing client applications. OGSA-DAI is designed to be extensible, so users can provide their own additional functionality.
- In this implementation, the **Geolinking Service (GLS)** is an application profile of the WPS. It links geographically related attribute data from a Geospatially-linked Data Access Service (GDAS) with geometric features from separate geospatial datasets (in this case, supplied by a Web Feature Service). A common geographic identifier is the prerequisite for geolinking.

- The OGC Web Feature Service (**WFS**) Specification allows the retrieval and update of geospatial data encoded in Geography Markup Language (GML). The specification defines interfaces for data access and manipulation operations on geographic features, using HTTP as the distributed computing platform. Via these interfaces, a Web user or service can combine, use and manage geo-data from different sources.
- The Geospatially-linked Data Access Service (**GDAS**) is an integral part of geolinking. GDAS delivers geographically related data (not geometries) in a simple XML format that can be used in a variety of ways. In this case, the GDAS stream is being merged in the GLS with the GML stream from the WFS to create an amended GML stream incorporating the additional attribute information provided by the GDAS.
- **UKBORDERS.** Part of the ESRC Census Programme, this online service from EDINA National Datacentre provides access to a wide variety of digitised UK boundary datasets. An OGC WFS interface has been made available to supply Census Output Area geometries for geolinking.
- **MIMAS Census Statistics.** Part of the ESRC Census Programme, the Census Disseminate Unit at MIMAS provides access to a variety of census data including UK Census Aggregate Statistics. A GDAS interface has been made available to provide a variety of census statistics for geolinking.

Business Process Modelling

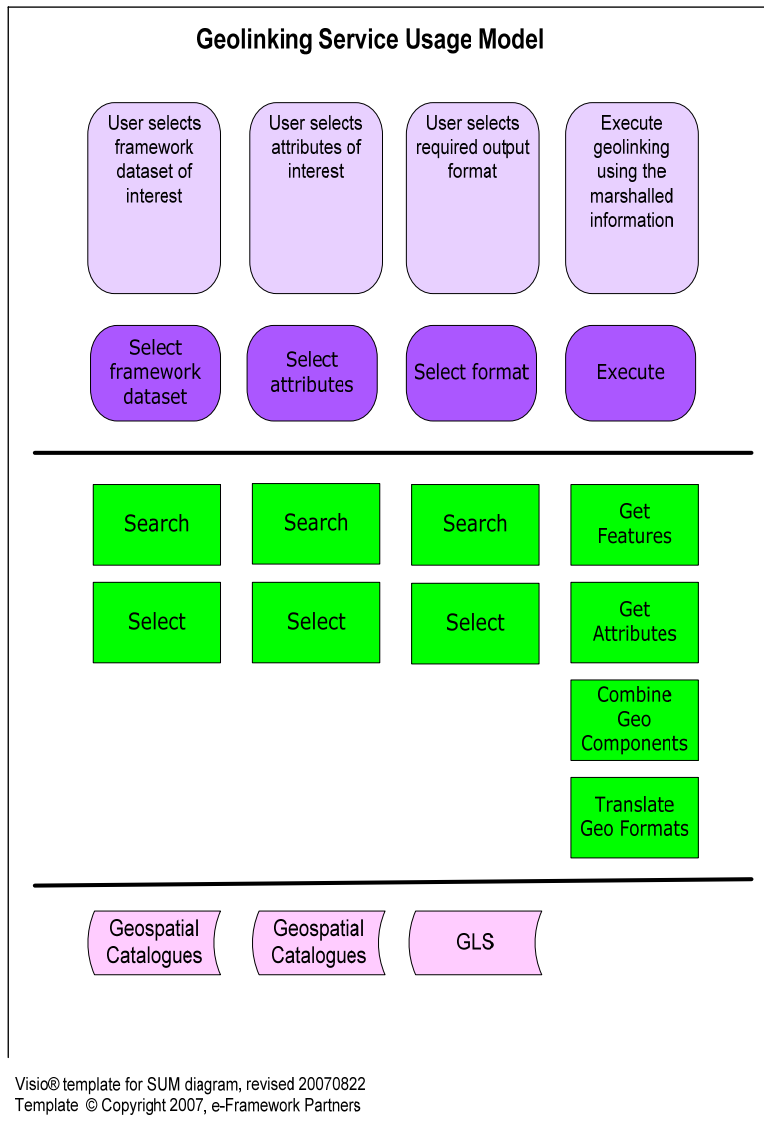
The business functions of the Geolinking SUM consists of the following processes:

- Discovering which content access services serving framework geographies, eg, census output areas, district boundaries, postcode areas, etc, are available for linking attributes to
- Discovering which attributes, eg, population counts, number of schools, long term unemployed, etc, are available for linking to framework datasets
- Obtaining geographic features for the area of interest from the framework dataset service provider
- Obtaining additional attributes for these features from the appropriate service provider
- Linking the attributes to the geographies at run time using an identified common field
- Generating a set of geographic features with enhanced attribution for the area of interest in a format usable by the consuming application

The OGC Geolinking Service [6] Discussion Paper contains additional material relevant to the business analysis motivating this SUM. Note however, that the standard effecting geolinking is, at the time of writing, still immature and subject to the OGCs specification programme.

SUM Diagram

Figure 2. Geolinking Service Usage Model



Usage Scenarios [optional]

The application created as part of the SEE-GEO project and outlined in the description section above was created using a Use Case [9] created by the National Centre for e-Social Science (NCeSS) Modelling and Simulation for e-Social Science (MoSeS) node [8]. The SUM could be used in a large number of scenarios; here is another example:

A student is engaged in research concerning provision of social services in the UK and health improvement. She needs information on the geographical distribution of British health status. Previously, she obtained the data from two resources: CasWeb (MIMAS) [10] and UKBORDERS (EDINA). She had to manually merged the retrieved datasets in a excel sheet. It required significant effort to compare and join the data; the student also spent a lot of time doing quality control.

The student now has the option of trying a new application that offers Geolinking. She opens a web browser window and logs into a web Portal. She first wants to find the geographic area of interest. She realises she can do this in three ways: from a drop down list which contains all area/region in the UK; from a bounding box coordinate input field which allows her to add coordinate values, or simply drag the box on a map. She selects "Leeds Local Authority District" from the drop down box. Accordingly, a list of census attributes appears in the *Census Attribute* selection area. She selects some desired census attribute, e.g. 'Limiting Long Term Illness', 'regionalism', etc. Then she presses the *Map Creation* button. Before processing the requests, the system asks her which map format she prefers: using a default Schema or Styled Layer Descriptor. She chooses the default setting.

The Geolinking Service pulls the requested data from two distributed data sources: the attribute data is obtained from MIMAS, and the boundary data is retrieved from EDINA. The result map image is pushed to a Mapping Portlet and rendered/displayed along with relevant information on the ranges of the attribute being mapped.

The student also obtains additional information and can easily view the figures with their graphic locations in the map. She simply downloads and inserts the new map image into his report.

Applicability [optional]

The GeoLinking SUM is applicable to geographically related information made available through SDI implemented using primarily the ISO/TC211 and OGC standards, the principles MAY be extended to other forms of data.

It is RECOMMENDED that the SUM is used with authoritative sources of framework data.

The GeoLinking Service Usage Model defines a simple access-only operation on the integrated datasets, uploading or updating datasets is restricted.

The data sources MAY be protected by authentication, authorisation or other forms of access control. The Geolinking SUM assumes the user holds the required access credentials.

Functionality

Select Framework Dataset: : this function allows a user to select the framework dataset of interest from a dropdown list. The Geolinking service as currently designed is preconfigured with the list of framework datasets it serves. This list may be updated regularly from a geospatial catalogue service. In the future, it may be possible to integrate geospatial catalogues to allow more sophisticated searching. The main constraint is always going to be ensuring the presence of a **Geolinkage Field**, ie, a field common to both the features within the framework dataset and the rows of attribute data to be geolinked

Select Attributes: this function enables users to select (by supplying a URL) which Geolinked Data Access Service (GDAS) is to be used. The application will then query the GDAS by issuing a

GetCapabilities request and, based on the returned capabilities XML document, populate a list of attributes that are available for linking to particular framework datasets.

Select Format: the user client application selects which output format the results are required in. This may be one of the well known and widely used GIS formats such as ESRI Shape, image formats such as *gif*, *jpg*, etc, or the actual data itself in the form of GML.

Execute: this function takes the information marshalled in the client application via the functions above executes the required geolinking. The workflow is instigated by the client application:

- **Get Features:** based on the users area of interest (specified in terms of a list of geolink IDs), geographic features are fetched from the framework dataset using a *Web Feature Service (WFS)*. As an example of a geolink ID, the census statistics and geographies linked in the SEE-GEO application use the "ONS_label" – this is a unique identifier issued by the statutory UK statistical agency, the Office of National Statistics (ONS).
- **Get Attributes:** based on the specified geolink IDs, this function fetches the statistics of interest. Via the *Geodata Access Service (GDAS)* interface, a simple XML stream is returned.
- **Geolinking:** the function provided by the service engine, which links the retrieved datasets based on the common geographic identifiers.
- **Generate Output:** another function provided by the GeoLinking service allowing the user to specify what format they want the output in. Depends on the application requirements and different implementations will support different ranges of output options. It may be desirable to have the output in a common GI format such as Shape files, or GML as with the SEE-GEO application.

Service End Point (Service Genre): Get

Supporting SUMs: WFS, GDAS

Primary Resource: Various RDBMS may be used and wrapped in WFS and GDAS interfaces. In the SEE-GEO example the geographical information from the UKBorders service was held in PostGIS and the MIMAS statistics in MySQL.

Secondary Resource(s): None

Objects: The WFS returns *Spatial objects* or *Geographic features* as defined in the ISO 19100 series of standards. These are encoded in GML

Structure & Arrangement

The output from this SUM can be either an image, ie, a map, which shows the distribution of a statistic of interest according to an appropriate framework geography, or raw data modified with additional attributes of interest to the user. The image can be in multiple different formats depending on the application (SEE-GEO returned ESRI Shape files). Data would typically be returned in GML. Both data and images are created through the interaction of number of services. The text below emphasizes that this SUM can be realized in a number of ways and is immature in that the standards relating to its implementation are still in flux. The SEE-GEO example is used again, with modifications where appropriate.

- The **Geo Linking Service (GLS)** client is used to create custom maps showing the distribution of a wide variety of health related statistics. It is used to solicit user input and marshal the parameters for issuing HTTP request to appropriate OGC Web Services. Some implementations in the future may find it desirable to use SOAP, especially if the functionality provide by the WS-Security suite of standards is being leveraged.

- This implementation was created within the context of the OGC Geolinking Interoperability Experiment (small scale collaborations between OGC members used to advance candidate specifications) when using a Web Processing Service (**WPS**) was the recommended approach. WPS is a generic mechanism to describe and web-enable a wide variety of geospatial processes. This is still a valid approach – although it would be better were a formal Geolinking WPS profile used or developed for the purpose. A separate GeoLinking specification may be created in the near future.
- The **Geolinking Service (GLS)** links geographically related attribute data from a Geospatially-linked Data Access Service (GDAS) with geometric features from separate geospatial datasets (in this case, supplied by a Web Feature Service). A common geographic identifier is the prerequisite for geolinking.
- This implementation of a GLS is parsing the WPS request, separating out the framework geography element, and forwarding it as an OGC Web Feature Service (**WFS**) request. This core OGC and ISO specification allows the retrieval and update of geospatial data encoded in Geography Markup Language (GML). The specification defines interfaces for data access and manipulation operations on geographic features, using HTTP as the distributed computing platform. Via these interfaces, a Web user or service can combine, use and manage geo-data from different sources. It should be noted that the GLS is agnostic about how the framework geographies are fetched, this is an implementation issue, it would have been equally valid in the case above to have queried a spatially enabled RDBMS directly.
- The Geospatially-linked Data Access Service (**GDAS**) is an integral part of geolinking. GDAS delivers geographically related data (not geometries) in a simple XML format that can be used in a variety of ways. In this case, the GDAS stream is being merged with a GML stream to create an amended GML stream incorporating the additional attribute information provided by the GDAS.
- **UKBORDERS.** Part of the ESRC Census Programme, this online service from EDINA National Datacentre provides access to a wide variety of digitised UK boundary datasets. An OGC WFS interface has been made available to supply Census Output Area geometries for geolinking. There is a wide variety of open source and proprietary WFS software available for wrapping geospatial databases.
- **MIMAS Census Statistics.** Part of the ESRC Census Programme, the Census Disseminate Unit at MIMAS provides access to a variety of census data including UK Census Aggregate Statistics. A GDAS interface has been made available to provide a variety of census statistics for geolinking. At the time of writing, this standard is immature.

Applicable Standards [recommended]

The main standards involved are:

- OGC Web Processing Service Specification 1.0.0, 05-007r7, 2007.
- OGC Web Feature Service Specification 1.1.0, 04-094, 2005.
- OGC Geospatially-linked Data Access Service, 04-010r1. Discussion paper.
- OGC Geolinking Service (GLS), 04-011r1. Discussion paper.
- OGSA-DAI: <http://www.ogsadai.org.uk/>
- Geography Markup Language (GML), 07-036, ISO 19136:2007

Implementation Guidance & Dependencies [optional]

The design and implementation of a Geolinking Service SHALL meet the following performance criteria:

- **Responsiveness**

The responsiveness is used to evaluate the speed with which a service can process a given request. It can be measured by the *Response Time* which is the average amount of time (in seconds) required for a service component to handle a request.

The implementation of the Geolinking Service SHALL present acceptable performance in term of efficiency of executing a service. Optimization strategies MAY be employed in the processes of data retrieval and linking, for example, caching the results both on client and server, reduce the data exchanging between clients and the service by merely exchange the updates rather than the whole datasets etc.

- **Throughput**

The throughput is measured in units of work accomplished per unit time. This measure is used to evaluate the quantity of requests a service can process. The implementation of a Geolinking Service SHALL be able to dealing with certain level of access scalability, and provide even throughputs in spite of increasing of user inquiries.

- **Availability**

The availability is defined as the fraction of the time a resource/application is available for use. It is measured by the percentage of time a service is able to execute. To improve the availability of a Geolinking Service, the behaviour of the service SHALL be monitored, and the failures of the service SHALL be reported immediately.

- **Security**

Authentication, authorisation or other criteria of access control MAY be implemented to protect the usage of the data resources.

- **Consistency**

A Geolinking Service implementation does not have to ensure that clients always get the latest updates from all data resources they request.

- **Interoperability:**

The purpose of the SUM is to achieve interoperability. An implementation MUST use the RECOMMENDED versions of the appropriate standards, primarily the ISO TC/211 and OGC open geospatial interoperability standards. At the time of writing, some of the standards used in the SUM, eg, GLS and GDAS, are immature and in flux. Up to date guidance from an appropriate SDI authority should be sought.

Known Uses [optional]

An implementation was developed as part of the SEE-GEO project and is being taken forward as part of the NCeSS infrastructure project.

Data Sources Used

In the SEE-GEO exemplar, the following data sources were used:

- **UKBORDERS.** Online data resource, from EDINA National Data centre provides access to a wide variety of digitised UK boundary datasets.

- **MIMAS Census Statistics.** The Census Disseminate Unit at MIMAS provides access to a variety of census data including UK Census Aggregate Statistics.
- **Others.** Note that it is relatively straightforward to plug-in other geographically related data resources via the OGSA-DAI data integration layer.

Related SUMs [optional]

WFS and GDAS

Services Used

The GeoLinking Service Usage Model uses the following Service Expressions:

- Search
- Select
- GET Features
- Get Attributes
- Combine Geo Components
- Translate Geo Formats

References

1. Secure Access to Geospatial Web Services (SEE-GEO) project
<http://edina.ac.uk/projects/seesaw/seegeo/index.html>
2. Infrastructure for Spatial Information in Europe (INSPIRE) <http://inspire.jrc.it/>
3. UKBORDERS. Boundary datasets of the United Kingdom. <http://edina.ac.uk/ukborders/>
4. GSDI Cookbook, Version 2.0 <http://www.gsdi.org/gsdicookbookindex.asp>
5. MIMAS <http://www.mimas.ac.uk/>
6. OGC Geolinking Service 04-011r (ed Peter Schut)
<http://www.opengeospatial.org/standards/dp>
7. Open Geospatial Consortium <http://www.opengeospatial.org>
8. Modelling and Simulation for e-Social Science (MoSeS)
<http://www.ncess.ac.uk/research/geographic/theses/>
9. MoSeS-NCeSS e-Infrastructure Use Case
http://www.geog.leeds.ac.uk/people/a.turner/organisations/OGC/GeoLinkingIE/MoSeS-NCeSS_e-Infrastructure_UseCase/#Version_0.0.3
10. CasWeb – Web interface to census aggregate outputs and digital boundary data.
<http://casweb.mimas.ac.uk/>
11. ISO/TC 211 Geographic Information/Geomatics <http://www.isotc211.org/>