

An interoperable Web Service Architecture to Provide Base Maps Empowered by Automated Generalisation

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Abstract. Producing customized base maps generated by automated generalisation on the web is an important issue in physical planning. In this web context an interoperable architecture is a key requirement. It integrates the necessary data and the functionality to finally perform the generation of the base map. Additionally, interoperability increases the reuse of the architecture for other domains. In this paper we will describe such an architecture. It has two key features: it supports the user profiles to specify the generalisation constraints and the generalisation-enabled WMS, which generates the base map according to the user profiles. The specialized WMS is especially able to access Web Service-based generalisation functionality. For the implementation of the architecture we used Geoserver, 1Spatial's Clarity and 52° North WPS.

Keywords: Automated generalisation, Web Service architecture, user profiles, physical planning

1 Introduction

Automated generalisation is a means to extract information by transforming data regarding scale and use. Most of the applications involving generalisation aim at map production. These maps are nowadays frequently provided on the web and are accessible through Spatial Data Infrastructures (SDIs) (McLaughlin & Groot 2000). Mostly maps are static and serve only a very general purpose, but the demand for highly customized maps is increasing. Data providers are forced to adapt their products to this changing market setting. In the context of producing and disseminating customized maps based on existing topographical databases, an interoperable Web Service architecture is an important prerequisite.

Research on automated generalisation in the context of Web Services resulted in different approaches (Sarjakoski et al. 2005; Edwardes et al. 2005; Harrower & Bloch 2006). One promising approach is to perform generalisation processes on the web using a Web Service architecture (Burghardt et al. 2005; Foerster & Stoter 2006). Applying this approach to produce and disseminate customized maps on the web is still missing. This paper presents an interoperable Web Service architecture producing customized maps by means of generalisation. Customization in this case is achieved by so called user profiles describing generalisation-related user-information, which drive the generalisation process.

This paper is motivated by the RO-online¹ portal (Ministry of Housing, Spatial Planning and the Environment 2008). This portal will be launched in July 2008 and aims at a web-based dissemination approach for physical planning maps of the Netherlands. It thereby meets the evolving requirements of e-government, public participation and cost-reduction. The physical planning maps that will be delivered through RO-online consist of the plan data and a currently available complete topographic map as base information. This base information is intended to be customized individually for each user group to provide adjusted base maps for better usable physical planning maps. The starting point for this paper is to develop an interoperable architecture, which generates and delivers such customized base maps for RO-online. Interoperability is a key aspect in this context, to be able to incorporate existing architectures such as RO-online, to be able to integrate generalisation functionality provided by other Web Services, and to be flexible for future requirements.

This project is of high interest for topographic data providers, as it touches the main issue of generalisation of topographic data to derive cus-

¹ RO stands for Ruimte Ordering (Dutch); in English: physical planning.

tomized maps. It is important to note, that this paper will not solve core generalisation problems, but it will show how generalisation can be applied in an interoperable Web Service architecture and how it might enable web-based dissemination of customized maps. Interoperability is an important aspect for sustainability of investments as it ensures the extensibility and the reuse of architecture components. From a technical perspective, interoperability is achieved through data and service standards (e.g. GML, WMS, WFS and WPS). Those standards are the building blocks of the architecture presented in this paper.

The main component of the proposed architecture is the generalisation-enabled Web Map Service (WMS²). It consumes the user profiles and provides the maps according to these user profiles. Therefore the WMS is extended with generalisation capabilities. In our implementation the generalisation-enabled WMS is empowered by an agent-based generalisation system (i.e. ISpatial's Clarity, Hardy et al. (2003)), which is a widely adopted implementation of the constraint-based generalisation approach. Additionally Clarity is extended to access distributed services providing generalisation functionality (i.e. Web Generalisation Services) and thereby to overcome its lack of functionality.

The paper will first introduce the project in detail and will explain the benefits of generalisation for the project. In Section 3 the paper will examine recent work in the context of generalisation and Web Service architectures. The proposed architecture will be described in Section 4. Section 5 explains some details about the already implemented components. Finally Section 6 will conclude and discuss the major aspects of the proposed architecture and will give some outlook for future work.

2 Physical Planning Maps on the Web

The currently ongoing shift towards e-government is relevant in the context of physical planning. The RO-online project in the Netherlands focuses on a web-based dissemination of physical plans and is the successor project of the DURP³ project, which developed an information model for

² More information on the WMS interface specification:
www.opengeospatial.org/standards/wms.

³ DURP stands for Digitale Uitwisseling in Ruimtelijke Processen. In English: Digital exchange for spatial processes.

exchanging digital spatial plan information (IMRO⁴) over the web (Ottens 2004).

The RO-online project develops a web portal to provide instant web-based access to physical planning maps, compiled of the evolving digital plan data plus available topographic data. The portal is based on an interoperable Web Service architecture for the dissemination of the maps (Fig. 1).

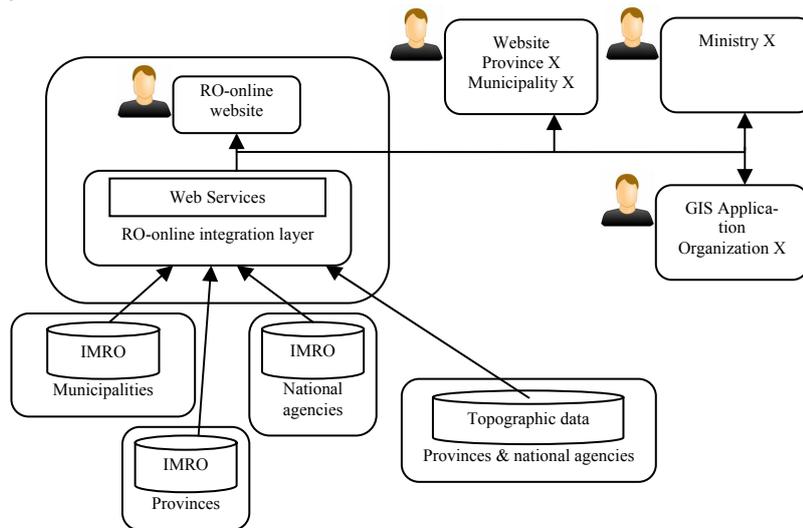


Fig. 1. The RO-online architecture incorporates Web Services (adopted from: www.helpdeskdurp.nl)

The topographic data that is currently used as base map is the complete topographical map at a certain scale (for example 1:10k or 1:50k) depending on the scale of the plan (municipal, provincial or national government level). Therefore the base map might be not optimally applicable to all user groups, as well as to new uses which are made possible by the new environment compared to the paper plans. For example, different physical plans can be combined in the portal and they can also be accessed in an interactive way (i.e. zooming). The map in Fig. 2 demonstrates that zooming might result in such a dense topographic base map, that the complete map might not be usable anymore. At least, the usability of such a map could be increased by a customized base map according to the zoom scale. Therefore the base maps have to be adapted to a specific user group but also to

⁴ IMRO stands for Informatiemodel voor de Ruimtelijke Ordening. In English: Information model for physical planning.

the way the plans are queried (integrated with other plans or not; at a specific scale).



Fig. 2. Example of a physical planning map (provincial plan with 1:50K topographic base map) – in the current static approach, this base map would not have been adapted while zooming

This was the starting point of the *DURP ondergronden*⁵ project, which focuses on a methodology to generate the most applicable base map for specific uses and specific user groups based on a topographic database by means of generalisation⁶. The methodology addresses usability-related and technological-related research (Poppe & Foerster 2006). This paper focuses on the latter one. The usability-related research identifies some key use and user requirements for the customized base maps which will be input for the technological-related research. The usability-related research will also yield requirements for the base maps laid down by the level of detail of the physical planning information. For example, a plan with accurate plan information can be portrayed on a detailed base map, whereas a plan that still contains fuzzy description of boundaries should not be portrayed with a highly detailed base map. These requirements are still under research. Therefore, the main requirement for the technological-related research is to develop an extensible architecture, which is able to serve customized base maps by the means of automated generalisation. The technical compliance with RO-online is a requirement for the architecture. An interoperable architecture assures that all information can be exchanged and integrated across systems. It is also important to note, that RO-online

⁵ DURP ondergronden: in English: DURP base maps.

⁶ DURP ondergronden project website: www.durpondergronden.nl.

can integrate the plan information in the architecture as proposed in this paper.

The generalisation will be implemented based on the Large Scale Base Map of the Netherlands (*GBKN* in Dutch) (scale range 1:500 – 1:1000) and TOP10NL (topographical database at scale 1:10 000). The generated base maps will be used in combination with physical planning data at local scale (Dutch: *bestemmingsplannen*) and at provincial scale (Dutch: *structuurvisies*).

3 Related Literature

3.1 Model versus Cartographic Generalisation

Research on automated generalisation has yielded a lot of concepts and applications in the last 20 years. A good overview can be found in McMaster & Shea (1992) or in the most recently published book of Mackaness et al. (2007). Different views on generalisation have been developed, such as the generalisation model by Gruenreich (1992), which separates generalisation into *model generalisation* and *cartographic generalisation*. Model generalisation is concerned with the transformation of data according to a target model and cartographic generalisation is aiming at producing maps out of data by avoiding cartographic conflicts. This approach defines a clear separation between data and representation. The separation seamlessly integrates with current software systems, which also follow this approach (also known as Model-View-Controller pattern).

Cartographic generalisation is about solving conflicts of cartographic features on the map. Cartographic features do already have symbolization attached. The relation of cartographic generalisation and symbolization is depicted in Fig. 3. The presented use case in this paper aims at cartographic generalisation, as it addresses the production and dissemination of physical planning maps.

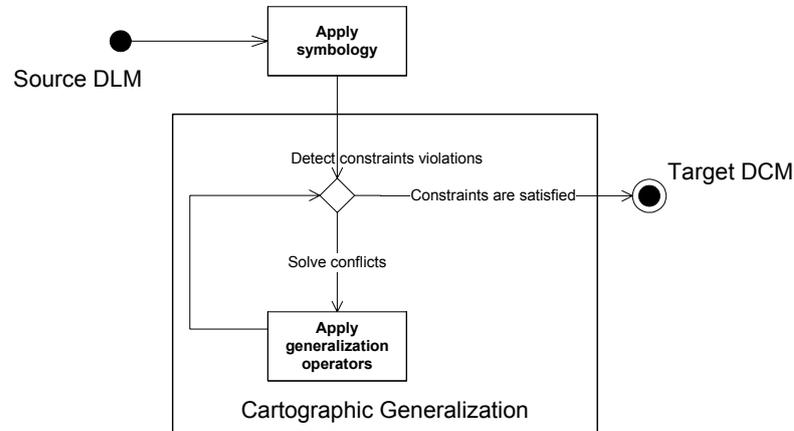


Fig. 3. Cartographic generalisation process

3.2 Constraint-based Generalisation

Constraints for generalisation have been introduced to overcome the complexity of rule formation of generalisation. They describe conditions that should be met in the output of the generalisation process. Beard (1991) proposed this approach because the established expert systems became too complex in terms of understanding, maintenance and reuse. The idea of constraints is thereby not to formalize of how to reach a specific goal as in the case of rules, but to describe the outcome (i.e. the final map). Lots of previous approaches applied the concept of constraints to implement sophisticated generalisation systems. As constraints might compete with each other depending on the specific cartographic objects and the scale, the generalisation process itself turns into an optimization approach. An overview of the different optimization approaches applying the concept of constraints is given in Sester (2005). In this paper we will utilize the generalisation system Clarity of 1Spatial, which applies an agent-based optimization approach (Lamy et al. 1999). Until now this system has been applied in a group of National Mapping Agencies (Magnet Consortium, Lecordix 2005) and yielded a lot of promising generalisation results as presented by Regnaud (2006) and Lecordix et al. (2007). Applying Clarity in the presented architecture demonstrates also its suitability for Web Service architectures in general.

3.3 Web-based Architectures for Generalisation on the Web

Interoperability is the capability of two components to communicate at run-time to meet a common goal (ISO/TC211 2005). Such interoperability is achieved by open standards-based software development. This was the starting point for research on generalisation to propose the Web Generalisation Service (Sarjakoski et al. 2005; Edwardes et al. 2005). The Web Generalisation Service is a means to share knowledge between researchers in terms of generalisation algorithms and to extend existing software systems by remotely available generalisation functionality. In this context Edwardes et al. (2005) introduced a classification of Web Generalisation Services according to their granularity. The classification distinguishes Web Generalisation Services into two classes, the compound generalisation service and the generalisation operator service. The compound generalisation service applies a sequence of generalisation operator services to carry out a complex generalisation process such as building generalisation. The generalisation operator service implements the idea of generalisation operators, as they have been introduced in early research about automated generalisation. The concept of generalisation operators provides an abstract view on algorithms and allows grouping them according to their functionality. Different kinds of functionality have been classified in a distinct set of operators. The latest attempt, which bases its classification on formal data models of ISO and OGC is published by Foerster et al. (2007a).

Currently there are two different proposals for implementing Web Generalisation Services. Foerster & Stoter (2006) suggest to apply the evolving OGC Web Processing Service interface specification (WPS⁷) and implemented it as the 52N WPS framework⁸, which is available under open source license at 52°North (Foerster & Schaeffer 2007). Burghardt et al. (2005) suggested the WebGen framework, which applies a concrete XML-RCP model to provide the generalisation functionality on the web. The WPS framework provides more functionality such as different clients. As the 52N WPS framework applies an OGC standardized approach (i.e. WPS interface specification) it provides a higher degree of interoperability in the future than the WebGen framework. Besides the research on Web Generalisation Services, Oosterom et al. (2006) proposed a Web Feature Service

⁷ More information on the WPS interface specification: www.opengeospatial.org/standards/wps.

⁸ 52N WPS framework website: www.52north.org/wps.

(WFS⁹) supporting progressive transfer to overcome the problem of inefficient data transfer.

In the context of generalisation research there are several projects addressing a web-based architecture such as the GiMoDig project (Sarjakoski et al. 2005) and the WebPark project (Burghardt et al. 2004). The latter one addressed cartographic generalisation in their architecture. They based their complete architecture on already existing standards such as Web Map Service and Styled Layer Descriptor (SLD¹⁰). This project focused on the dissemination of mobile maps and made no attempt to serve different generalisation needs of different user groups in a flexible way. The WebPark project only took into account different symbolization options, determined by different SLD documents during the generalisation process (static rules) but did not include the concept of user profiles (i.e. user-specific generalisation constraints). Additionally the WebPark project did not apply any Web Service generalisation processing, as it is presented in this paper.

4 Design of the Architecture

4.1 Generating the Physical Planning Map

Before introducing the conceptual overview of the architecture and its components, this subsection addresses the logical issues related to the generation of the physical planning map inside the architecture. This physical planning map is a combination of the requested planning information and the customized base map (finally available through RO-online). It will be a result of generalised topographic information meeting requirements as specified in the user profile, including requirements for symbolization of topographic objects. As already mentioned, the topographic symbolization drives the selection of the topographic feature types and their initialization as cartographic features (Section 3, Fig. 3). The symbolization of the physical plan has been set up in a legal process, in which all the Dutch planning authorities participated and is thereby predefined for the resulting map.

⁹ More information on the WFS interface specification:
www.opengeospatial.org/standards/wfs.

¹⁰ More information on the SLD specification:
www.opengeospatial.org/standards/sld.

To illustrate how the user profile dictates the generalisation of the base map, we define two constraints which could be part of a user profile. It is important to note that those constraints are only exemplary, thus in a user profile for a real application there might be also more constraints defined:

- a) topographic objects should never cross the boundary of the overlying planning object and
- b) the building objects should never exceed a certain minimum size on the map.

Those two constraints already have a huge impact on the generalisation of the map. Depending on the map situation (i.e. density of cartographic features and map scale) any generalisation action such as aggregation, enlargement or simplification could harm one of the two constraints. An example of such a map situation is schematized in Fig. 4. Although the example is simple and the solution might not meet cartographic criteria, it demonstrates how constraints encoded as user profiles can drive the generalisation process individually in the proposed interoperable architecture. As mentioned before, the constraints are based on usability-related research, which captures the information defining needs, interests and preferences of the user towards the base map. The constraints are thereby only a concept to transform the findings of the usability-related research into a representation, which can be used as an input for the generalisation system to produce a proper map. The constraints are statically defined and the client application will not be able to change the constraints dynamically. It is important to note, that further issues related to the formulation and verification of such constraints is outside the scope of this paper, but will be addressed in future research. In this context future research will also address the formalization of constraints using for instance the classification of constraints as proposed by Burghardt et al. (2007). The formalization might be expressed using the Object Constraint Language (OCL) (Warmer & Kleppe 2003).

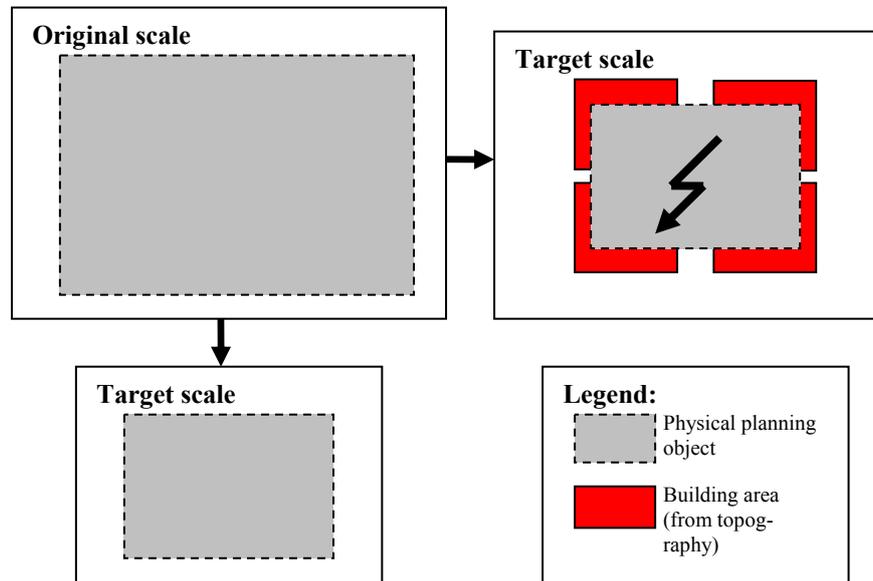


Fig. 4. Generalisation example with the topological constraint – The boundary of the planning object restricts the cartographic objects to move outside by typifying and scaling (e.g. upper left). However, aggregating is allowed (bottom left)

4.2 Components of the Architecture

The core component of the architecture is a mapping component, which produces and delivers the physical planning maps including the customized base maps. As the architecture aims at Web Services usage, this mapping component has to be able to access the different data services and has to be able to generalise the data by also accessing Web Generalisation Services. Additionally, as the produced maps have to be accessible from RO-online, the mapping component has to be a Web Service as well. For this reason our proposal is to develop a generalisation-enabled WMS. It is an extension of the WMS interface, as it has to consume the user profiles, to be aware of the generalisation requirements of the specific (remotely located) user. It is important to note, that by consuming remote user profiles, the architecture is in principle capable to serve a physical planning map regarding any set of constraints. Thereby the generalisation-enabled WMS has not to be configured for any newly introduced user group. Additionally the generalisation-enabled WMS has to handle the symbolization for the topographic data, which is specific to each user. This is achieved by SLDs, which are part of the WMS interface specification. To increase the degree

of interoperability and to make use of remote services, the generalisation-enabled WMS retrieves the required data for the physical planning map (i.e. physical planning data and topographic data) from WFS.

During the generalisation process, the generalisation-enabled WMS, will access remote generalisation functionality, hosted on Web Generalisation Services (deployed as OGC WPS). The applied Web Generalisation Services in this architecture are intended to be atomic and provide functionality on the generalisation operator level (Foerster et al. 2007). Such services are called Operator Services (Edwardes et al. 2005). The term atomic refers to the functionality of the Generalisation Web Service, which is standalone and only performs generalisation upon a designated part of data and follows thereby the concept of generalisation operators. Applying atomic functionality in a complex sequence of generalisation functionality is promising as it will allow designing a robust generalisation process, in which the single atomic processes do not interfere with each other.

An overview of the introduced components is given in Fig. 5. The WFS serving the data and the client could be used from RO-online. This already shows that the generalisation-enabled WMS is finally easily applicable to the RO-online architecture or any future application.

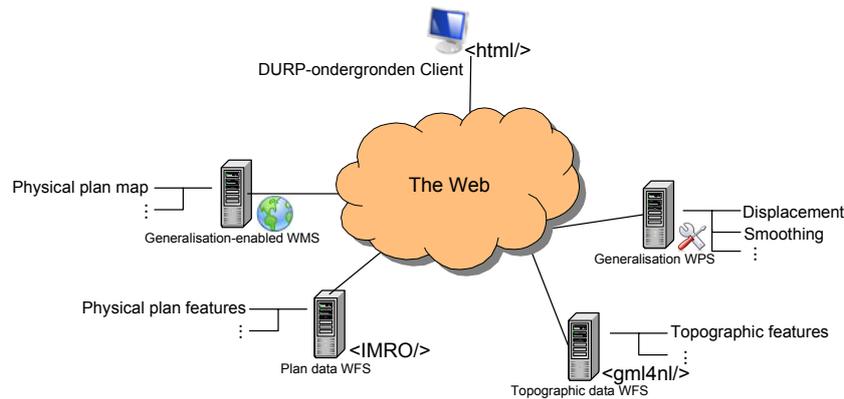


Fig. 5. Components of the interoperable architecture for producing, disseminating and displaying the physical planning map

4.3 Exemplary Architecture Walkthrough

This subsection describes the interaction between the introduced components in more detail. Those interactions are depicted in Fig. 6. We start with the client application (i.e. the DURP ondergronden client application), in which the end-user selects his/her applicable user category (e.g. citizen, architect etc.), the location, optional zoom-level and the specific

type(s) of plan information. Each user category is associated internally inside the client application with a user profile and a description of the topographic symbolization. The client application is implemented as a browser-based application, which allows easy integration with other portals such as RO-online. The client application requests a physical planning map (containing both plan information and a base map) from the generalisation-enabled WMS via the *GetMap* operation with some default parameters (map extent, map size), the SLD and the user profile.

The SLD describes the cartographic model for the topographic data encoded as XML. The user profile, which specifies the constraints (Section 4.1), will be incorporated as a vendor specific parameter into the WMS request. It is important to note, that customizing of the WMS service interface via vendor specific parameters is compliant to the WMS specification. The encoding of the user profiles might change with the outcome of the user-related research. However, for the prototype a plain XML-encoding of the constraints (as used in ESRI's prototype Optimizer (Monnot et al. 2007)) is sufficient. It is important to note, that the generalisation-enabled WMS will also be able to render the planning map without the user profile, in which case the WMS only applies some default generalisation constraints.

Based on the requested physical planning map and the spatial extent, the WMS retrieves the physical planning features from the plan data WFS. Additionally based on the spatial extent plus the listed topographic feature types in the SLD, the generalisation-enabled WMS retrieves them accordingly from the topographic data WFS. The WFS communication is based on the *GetFeature* operation and returns GML-encoded features. The features are encoded regarding the specific schema of the physical planning data (IMRO) and the topographic data (TOP10NL or GBKN). The WMS converts the retrieved data into cartographic features by applying the specific symbolization. The symbolization for the physical plan is fixed, but the symbolization for the topographic features depends on the SLD. All these cartographic features are added to a map. For the further transformation of the map by means of generalisation, the physical planning features are immutable and will not change. During the generalisation process the topographic features will be transformed according to the constraints (as specified in the user profile) to produce the customized base map.

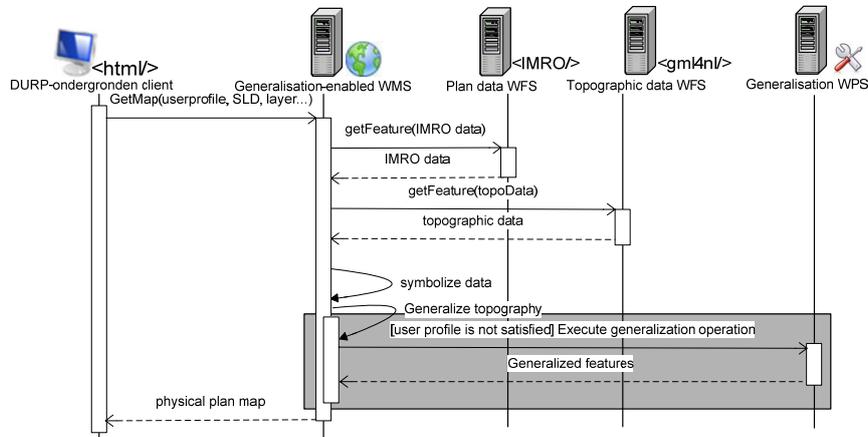


Fig. 6. Interaction within the interoperable architecture - the gray-shaded box marks the complex generalisation processing

During the generalisation process (emphasized in a gray-shaded box, Fig. 6), the generalisation-enabled WMS calls not only local generalisation algorithms, but also remote generalisation algorithms, which are hosted by Web Generalisation Services. The Web Generalisation Service is called by the *Execute* operation according to the WPS interface specification. It is important to note, that the sequence of involved algorithms is not fixed, but depends on the actual map situation (i.e. density of cartographic features and map scale) and the user profile. An example of a map situation and a user profile is given in Section 4.1. The generalisation-enabled WMS carries out the appropriate generalisation process according to the constraints described in the user profile.

5 Implementation of the Architecture

This section describes the on-going implementation work. As one of the project requirements is to apply open source software whenever it is feasible, Geoserver¹¹ was chosen as the appropriate software implementation of WMS and WFS. The reason for choosing Geoserver is manifold, at first it is written in the java programming language, at second it provides a comprehensive configuration tool for its services and at third it can be extended easily through *datastores*. The Web Generalisation Service is based on the 52° North WPS implementation (52N WPS) and the browser-based

¹¹ Geoserver website: www.geoserver.org.

map client is based on OpenLayers¹². ISpatial's Clarity is used as generalisation system for the generation of the customized base map as it implements the promising approach of agent-based generalisation (Section 3.1).

The implementation is still on-going. Here we present the parts that were finished as well as the experiences. Geoserver and the 52N WPS are already installed in our test environment as well as the data. In a first attempt, all data are inserted directly in the Clarity database, as we want to focus on the implementation of the generalisation-enabled WMS, which is the core component of the architecture and the main challenge of this project. In a final architecture setup, the data services will be provided by RO-online anyway.

The generalisation-enabled WMS is realized as a combined software component of Clarity and Geoserver. This is possible for three reasons: a) Clarity and Geoserver are written in the java programming language, b) Clarity can be loaded from another application through its underlying Application Programming Interface (i.e. Gothic API) directly and c) Geoserver allows embedding external software applications by the means of datastores¹³. Especially the concept of datastores provides Clarity all specific request parameters of the client application (user profile, SLD) to perform the generalisation individually.

The implementation architecture of the generalisation-enabled WMS and its *ClarityDatastore* is depicted in Fig. 7. The following course of action is performed by the generalisation-enabled WMS, whenever it receives a *GetMap* request specifying user profile (constraints), SLD (symbolization), location and scale: At first Geoserver hands the request over to the ClarityDatastore. The ClarityDatastore configures the Gothic database through the Gothic API by applying the symbolization (as described in the SLD) and passing the constraints (as described in the user profile) to it. The Gothic API performs the generalisation on top of the Gothic database by calling the local and remote generalisation functionality (e.g. Web Generalisation Service implemented as OGC WPS). In a first attempt the knowledge of remotely available generalisation functionality is incorporated by the concept of actions (e.g. generalisation algorithms) in the Gothic API. By using the concept of actions it is totally opaque to the Gothic API if it calls a local algorithm or a remote functionality hosted on a Web Generalisation Service. It calls the generalisation functionality depending on the map situation and on the user profile. Nevertheless, Clarity

¹² OpenLayers website: www.openlayers.org.

¹³ The concept of datastores is inherited from geotools, as it builds some parts of the backbone of Geoserver.

carries out the plan finding, the execution of the plans and the evaluation of the received generalisation results internally. Afterwards all the generalised data will be handed back to the Geoserver application. This forwards the result as a map back to the requesting client application.

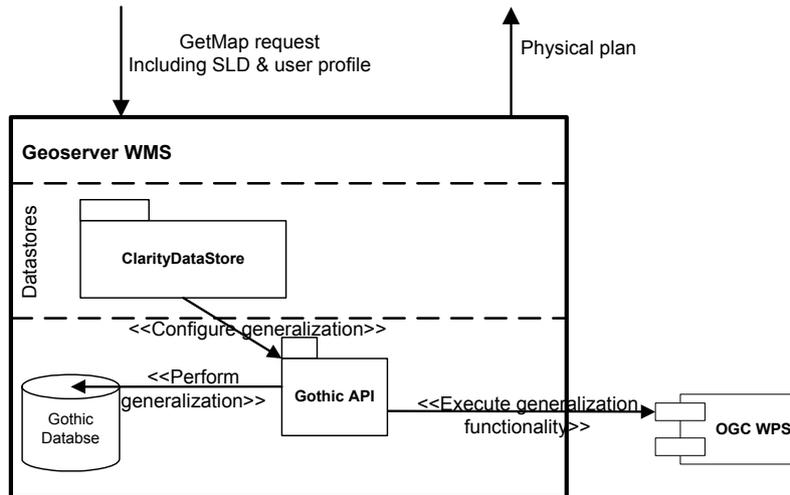


Fig. 7: Implementation architecture of the generalisation-enabled WMS (OGC WPS provides specific generalisation functionality such as displacement, simplification)

Regarding the generalisation-enabled WMS, the most important part of this software architecture is the coupling of Geoserver with Clarity (i.e. the ClarityDatastore). We will briefly introduce the design of the ClarityDatastore (Fig. 8). The coupling of Clarity (i.e. Gothic API) is realized by implementing three interfaces. The *ClarityDatastoreFactory* implements the *DatastoreFactorySpi* and has to maintain the connection to the Gothic database which is represented by the *ClarityDatastore* class. This is representing the *AbstractDatastore* and provides access to the actual data. It has thereby to configure the Gothic API with the specific symbolization and the user profile and to execute the generalisation. The result of the generalisation will be provided by the *ClarityFeatureReader* which allows Geoserver to access the generalised features finally by the *FeatureReader*.

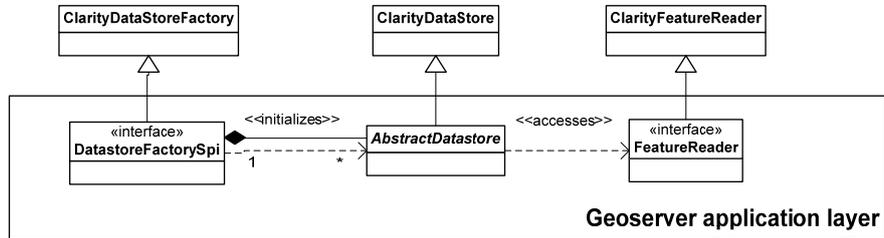


Fig. 8: Class diagram demonstrating the link between the geoserver implementation and Clarity

At the current stage, the design of the generalisation-enabled WMS is finished. It already shows that the proposed architecture is effective. In a first step, we will develop the ClarityDataStore as described in this section (Fig. 8). In a second step we will enable the generalisation-enabled WMS to access Web Generalisation Services. This will be done statically at first by preparing actions within Clarity, which connect specific remote generalisation algorithms through their endpoint URL. However, Clarity already accesses those remote algorithms automatically through the concept of actions. Finally, Clarity should be able to automatically search for different generalisation functionality on the web and incorporate it on-the-fly. This automatic approach also addresses the need for a semantically enriched description. Such a description is required to ensure meaningful interaction with the generalisation functionality and finally to produce usable generalisation results. A first attempt to solve this problem is to combine the proposed classification of operators (Foerster et al. 2007a) with the approach of application profiles for processes. In the future more sophisticated approaches should be applied such as developed in Lemmens (2006) and proposed by Regnauld (2007).

In the final prototype setting, we will incorporate the generalisation-enabled WMS into RO-online by accessing their data services and linking the developed WMS client application to the RO-online portal.

6 Outlook & Conclusion

This paper is motivated by the RO-online project, which provides physical planning maps via the Web. However, RO-online does not address the aspect of customized base maps, which increase the usability of physical plans, especially now they are no longer only available as single plans on paper, mapped at a specific scale. This paper addresses the issue of generating customized base maps by proposing an interoperable Web Service

architecture, which supports the production and dissemination of such customized base maps. The aspect of interoperability enables a high degree of portability and reuse of the architecture and thereby allows the adoption of customized base maps for other applications. The customization of the base maps is achieved by the means of automated generalisation.

The customization of the base map is driven by user profiles, which specify the constraints for the generalisation process individually according to the specific user. In order to generate maps according to such user profiles, the core of the architecture is the generalisation-enabled WMS. It accesses the remote data services and performs the generalisation process according to the posted user profile (Fig. 5; Fig. 6). The generalisation-enabled WMS requests remote generalisation functionality if required, which is hosted on Web Generalisation Services.

The designed prototype is deployed to a large extent on open source software. The generalisation-enabled WMS is realized by an internal coupling (i.e. datastore) between the Geoserver WMS and the generalisation system Clarity (Fig. 7). Overall Geoserver has demonstrated a clear design by the means of datastores to integrate existing applications for mapping purposes. The Web Generalisation Services will be incorporated by the means of actions into Clarity and allow Clarity to utilize local or even remote generalisation functionality.

Looking at the proposed architecture, there are still some issues left open to be addressed. To increase the interoperability of the architecture, the meaningful description of the Web Generalisation Services is a crucial issue. As already proposed, application profiles for processes or even describing the services by the means of semantic web technologies will enable an automated and meaningful discovery and execution of Web Service-based functionality. By now, the Web Generalisation Service instances are incorporated by manually linking their endpoint URLs into the generalisation-enabled WMS. However, the execution of the remote functionality is achieved automatically by Clarity.

Another crucial aspect of the architecture is its real-time performance. Executing the complete course of action, as it is described in the paper, might lead to bad performance of the architecture. Therefore, certain mechanisms for caching of already generalised maps might be helpful. It would allow processing the map once, but serving it multiple times. Research should analyze the most crucial parts of the architecture in terms of performance and propose feasible solutions. Such solutions could range from the tiling of maps to caching of generalisation results at the Web Generalisation Service. Also approaches of progressive transfer, as it is demonstrated for Web Services already by (Oosterom et al. 2006), might improve the performance of the architecture.

In the near future we will focus on further implementation of the proposed architecture, as it is already described in Section 5.

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¹⁴ RGI stands for Ruimte for Geoinformatie (in English: space for geoinformation); project website: www.rgi.nl.

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