GEOAVALANCHE - SPATIAL DATA INFRASTRUCTURE FOR AVALANCHE AWARENESS WARNING

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ABSTRACT: Avalanches are a serious problem across the Alps even more in the latest years, considering the number of people playing outdoor activities on snow areas. Dissemination of information across those stakeholders involved in all warning and rescue services is crucial at each stage. This paper figures out how people involved in risk mitigation might be allowed to fill this gap and exchange information in a common language both in term of contents and contexts without any kind of misleading. Furthermore, several user-oriented services might be acted on Web channels to reach mountaineers via mobile devices and make their experience safe-effective.

GeoAvalanche is an open-source project aimed at sharing information on snow avalanche (such as bulletins, incidents, snow-profile, weather observations…) with a common standard in order to build a Spatial Data Infrastructure for cross-border interoperability and early warning alert systems toward a safe mitigation risk of mountain activities across the Alps. The GeoAvalanche server has the OGC Web Feature Service capabilities to enable common warning services for snow avalanche information exchanges in compliance with CAAML (Canadian Avalanche Association Markup Language) specification (adopted by the avalanche community as an international standard) and map visualization services for incident report and bulletin alert.

1 STATE OF THE ART

Environmental risk management is a major scope issued by INSPIRE directive. The theme “Natural Risk Zones” asserted in the Annex III identifies all atmospheric, meteorological, hydrologic, geological and wildfire phenomena that, because of their location, severity, and frequency, have the potential to seriously affect population.

Specifically, it defines particular areas with significant snow cover combined with steep slopes – amplified by snowdrifts – that are prone to influence the occurrence of avalanches and snow slides.

In this context, the investigations and the underlying purposes mainly concern the provision of a suitable Spatial Data Infrastructure (SDI). This would give the opportunity to interoperate with systems aimed at regulating the land use and the resource management in areas under certain restrictions and linked to such risk, and would provide a web mapping of those areas susceptible to snow slides by dividing them into zones according to different risk classes [INSPIRE].

A first example of geographical feature – as tool mostly known by the public – is the bulletin that is issued according to the avalanche danger scale whose risk levels are now commonly accepted and universally recognized by all organizations. This standardization conceives a reference to the mapping of those areas at risk, and allows representing thematic maps with a unique legend that can be understood worldwide.

Despite the treat of avalanche bulletins in a map [Nairz, P.] has been recently examined, modern information systems show a weak use of geospatial standards that should be in support of interoperable services among organizations and would consequently lead to a snow avalanche data infrastructure with a solid basis.

2 OBJECTIVES

Avalanche Warning Services (AWS) in Europe daily collect meteorological and snow data for their nowcasting and forecasting products.

Usually, an avalanche center has to inform the relevant authorities in order to let them immediately take actions and effectively alert recreational users to the possible danger of avalanches in those areas where they are planning to venture (i.e.: ski-touring, mountaineering, snow shoeing, etc.).

Therefore the information system of choice must be accurately designed with geospatial standards in mind that lead to interoperability between applications, systems and communication through all possible Web channels [Hervàs, J.].

Consequently it will be easier to be able to achieve decision-makers and third-party alpine
service providers as well as end-users with their mobile devices (Smartphones, iOS, Androids). In addition, this would strengthen the network of observation centers because currently a nationwide fragmentation of the forecast seems to be evident and often the harmonization of the final products is actually weak. This delay is even more accentuated at cross-border level where AWS aren’t allowed to access real-time data on contiguous area belonging to neighboring countries because a shared information system covering mountain areas is still missing.

The relevance of data sharing among avalanche organizations resides hence on the geographical nature of the information, which they publish on daily basis.

In order to make the most effective use of data and since their spatial component, it is crucial that AWS have to collect them through modern geographic information systems (GIS) [Magnússon, M.M.] and geospatial database. Nowadays, these organizations need to structurally treat all information related to their observations and to offer advanced monitoring services for hazard and resource management rather than just avalanche maps.

This work intends to propose a solution to the problem through the use of a robust geospatial product that has been further evolved to adapt with the Canadian Avalanche Association Markup Language [CAAML], a commonly used semantic in the snow avalanche domain.

The objective of this solution is to improve the current cooperation of avalanche centers and the services that they are providing over the Internet for the general public.

3 GEOAVALANCHE PROJECT

3.1 Scope of the initiative

GeoAvalanche is an experimental open source project aimed at designing, developing, and testing functionalities and architectures that establish a wide methodology able to deal with snow avalanche datasets in a common way by ensuring interoperability among cross-border, national and subnational organizations based on geospatial standards in the realm of Open Geospatial Consortium [OGC].

Overcoming the current lack of cooperation and accessible services for the public, this project wants to point out a basic tool for improving collaboration among risk management offices and serving a reliable product for alerting.

GeoAvalanche server results in accessing the aforementioned datasets and making them available by using OGC Web Feature Service (WFS). It is also intended to provide maps of all stored geographical features (i.e.: bulletins, etc.) through OGC Web Mapping Service (WMS) in order to publish them on third-party Internet sites and on mobile devices equipped with geolocalisation services.

It would be a core component for an upcoming snow avalanche data infrastructure that benefits from all the main features of the geospatial Web.

3.2 Snow avalanche standards

3.2.1 Avalanche Danger

Avalanche bulletins are basic tools providing an overview of the snow cover as well as the state of the snowpack by pointing to the avalanche danger issued in a given territory – according to the weather forecasts and the snow profile evolution – for warning purposes so as to contrast the triggers of avalanches and, therefore, possible incidents.

This assessment, whose semantic rules are standardized in Europe by the European Avalanche Warning Service organization (EAWS), is carried out for each region by giving out a shortly text description on the basis of avalanche danger. It also contains the edge of the snow, dangerous places or elevations with critical rose of aspects, and finally a graphical representation in a map showing the color theme related to the danger level and the corresponding text portion [Chiambretti, I.].
Avalanche danger scale is then encoded according to the European-wide standard currently used at EAWS and divided into 5 classes (1-Low, 2-Moderate, 3-Considerable, 4-High, 5-Very High) related to the relevant safety information provided to the user.

3.2.2 CAAML

This semantic is an XML grammar language initially developed in 2003 and currently used by the Canadian Avalanche Association to provide a shared encoding structure as well as the exchange of snow avalanche related information over the Internet.

The feature types currently supported by CAAML are the following:

- Avalanche incident information
- Avalanche activity comments
- Avalanche observations
- Avalanche bulletins
- Avalanche closures
- Observations on the field
- Snowpack structure comments
- Snow profile observations
- Weather observations

Since the nature of CAAML strictly derives from GML, it was designed with the same flexibility. Actually, this recent version borrows the concept of profile from GML, which allows dealing with a logical limitation of the elements relevant to a specific application while keeping the ability to be validated against the overall CAAML standard. Current experiments investigated a profile suitable among the EAWS agencies for their CAAML-scoped avalanche bulletins. This specific schema file is currently maintained at this location http://caaml.org/Schemas/V5.0/Profiles/BulletinEAWS/CAAMLv5_BulletinEAWS.xsd

Figure 3 shows how a bulletin element has to be semantically expressed in the European profile.
This data type is a kind of complex feature that needs to be further exploited in order to explain how it could be published through an endpoint service.

The present approach doesn’t mean that GeoAvalanche architecture was designed for a limited set of CAAML profiles but, instead, it means that it was designed to handle any of them. As a result, the GeoAvalanche server would be able to manage the exchange of any profiled elements and, hence, to achieve interoperability at different levels (regional/national/european).

3.3 GeoAvalanche Server

GeoAvalanche server is built upon GeoServer [GeoServer] then equipped with its plugin for supporting third-party GML application schemas. This latter functionality allows serving complex snow avalanche features encoded by CAAML. The project is developed under GNU General Public License v3.

3.3.1 GeoServer

GeoServer is the reference implementation of OGC Web Feature Service (WFS) standard, and also supports OGC Web Map Service (WMS). WFSs are of particular interest for data interoperability because, unlike a portrayal service such as WMS, they allow directly querying the underlying data. GeoServer is a powerful geospatial engine able to aggregate different datastores at a single point and to let them be republished as cascaded Web Services from distributed sources including also remote WFS as shown in the following figure.

As the support for GML 3.2.1 is already developed, GeoServer can comply with the INSPIRE Directive that requires to issue WFS services in accordance with the above-mentioned GML version.
3.3.2 **Snow avalanche application schema support**

GML application schemas can indiscriminately represent complex information models such as CAAML for snow avalanches. GeoServer application schema support is applicable to CAAML thanks to spatially described information that is represented in complex features expressed as GML 3.2.1 application profile. It is currently maintained as a standard GeoServer plugin, which makes use of the simple feature access provided by GeoTools and converts each of them – retrieved as database tables – into complex features by using mapping rules.

As a single `caaml:Bulletin` can be observed at several different locations on the Earth’s surface, it can have one of the multivalued `caaml:bulletinResultsOf` properties, each of them being a `caaml:BulletinMeasurements`. The resulting mapping can be depicted as shown in figure 5.

GeoAvalanche deployments also include a spatial DBMS, such as PostGIS, to supplement GIS functionalities for CAAML complex features and, therefore, they become together a good fit for all those features that you might expect from a SDI.

The GeoAvalanche component within a CAAML data infrastructure plays a key role because it manages both read and write operations regardless of the database schema used to store such data. It can perform WFS filter queries and also acts according to OGC WFS-T transactional specification because each single service is conformed to the same CAAML application schema [Caradoc-Davies, B.].

On the other hand, its service-oriented architecture allows exploiting lightweight format like GeoJSON for consuming data from mobile, custom-client and any third-party system. A straightforward request for bulletins can be expressed as follows:

```http
http://localhost:8080/geoavalanche/avy/ows?service=WFS&version=1.0.0&request=GetFeature&typeName=avy:bulletins&outputFormat=json
```

and further refined in order to filter out appropriate macro-zones through a CQL syntax like `cql_filter=(res="Monte Rosa")`.

4 **SPATIAL DATA INFRASTRUCTURE**

Interoperability is the first step towards a snow avalanche data infrastructure where distributed observation centers and central avalanche warning services can mutually exchange them through a shared semantic structure. GeoAvalanche server offers a wide flexibility in building a nationwide network of regional AWS departments. In fact, once the national authorities decide to leverage regional offices to using CAAML, GeoAvalanche will play a key role in setting up a new prospect of data-driven services. This paper is highlighting the approach on the data exchange rather than their visualization. This is regularly possible thanks to the maturity of GeoServer that offers default out-of-the-box capabilities to display maps via WMS standard implementation and, hence, that will
lead to easily deliver thematic maps of their nowcasting and forecasting products. Actually, each single office could potentially implement its own CAAML-based server and act either as a remotely accessible node that simply collects observations, or as a regional warning service that provides the end users with final local products.

The relevance of this methodology is mainly its ability to compose aggregated maps rather than limited and to easily support the integration of existing CAAML tools in a transparent way. As a result, our proposal for a preliminary European CAAML Spatial Data Infrastructure is issued as shown in the figure 6.

This architecture relies on a distributed service-oriented paradigm essentially based on the underlying cutting-edge technologies for the GeoWeb by strengthening the use of CAAML and making GeoAvalanche the basic building block for the Web 2.0 tools across the snow avalanche community.

By using these integrated technologies, forecasters and officers will be able to respond to several risks (avalanches, hydropower resource, technological) by using the following tools:

- National integrated platform to manage distributed sources of snow avalanche observations through an interoperable mechanism;
- Avalanche Bulletin Map widget, at either national or subnational level, which retains maps of nowcasting and forecasting and other relevant information (incident reports, snow cover, snow quality, etc.) with the possibility to access third-party services for data fusion capabilities;
- On-demand Warning Services by using RESTful endpoints for retrieving reports of snow depth, daily, weekly and monthly snow water equivalent, and more specifically located alerts about bulletins, main closures (highways, local roads, ascents), severe weather conditions, etc.;
- Transnational data catalogue for discovering data and services about snow avalanche information and consequent resources (water, energy, etc.) with a shared legend and glossary;
- European Avalanche Map Composer for producing cross-border maps and collapsing national hazards into simple view of governance tools.

Figure 6: Proposal for a European snow avalanche Spatial Data Infrastructure
5 RESULTS AND CONCLUSIONS

The system was easily prototyped and tested to focus on a simple CAAML datastore in order to effectively demonstrate the feasibility of such experimental SDI. However, the results have to be locally validated with reference to a real environment so as to centrally collect – at a national avalanche agency – data from distributed sources and then to publish avalanche bulletin maps of the underlying regions.

The development of an SDI among avalanche centers (and other possible stakeholders) based on GeoAvalanche will ensure data sharing, interoperability, and more accurate information for nowcasting and forecasting purposes. From an application viewpoint, the use of its WFS services would achieve an interoperable network among either EAWS agencies or liaison regional offices, and would further leverage new improvements to develop innovative services of early warning systems which take into account the safety of backcountry tourists as well as some qualitative information on the snow.

The solution would be able to obtain:

- At European level: a snow avalanche geoportal collecting data from each member state and representing a contribution to define natural risk zone to INSPIRE;
- At National level: a geospatial tool providing avalanche bulletin maps, value added
- At Regional level: a measure integrating the observations collected from the ground in a format easily shared, commonly agreed, and useful to a single national container for such information.

6 FUTURE WORKS

Despite the outcomes confirmed the ability to exchange snow avalanche datasets with a standard common language, more challenges can be raised. Actually, the upcoming implementation of services requiring compliance with the INSPIRE data themes needs to be further investigated and a schema transformation for CAAML datasets needs to be defined. Furthermore, interoperability has to be complemented by catalogue functionalities so as to offer search capabilities on avalanche metadata and, thus, to improve the impact on the user experience.

Therefore, future works will be focused on developing Catalogue Service for the Web (CSW), which will enable extended WMS configuration for serving relevant WMS 1.3 bulletin alerts to map visualization services that comply with INSPIRE.

REFERENCE:


GeoServer, http://geoserver.org


Hervás, J., 2003, Recommendations to deal with Snow Avalanches in Europe, NEDIES project, 71-75, Ispra (VA), Italy, Joint Research Centre.


Magnússon, M.M., 2003, Recommendations for the prediction of avalanches, NEDIES project,
10-19, Reykjavik, Iceland, Department of Research and Processing, Icelandic Meteorological Office
