

Geospatial ICT Support for Crisis Management and Response

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ABSTRACT

Efficient crisis response and management requires well-informed actors and stakeholders and effective means for communication and policy enforcement. A secure and dependable geospatial information and communication technology (ICT) infrastructure may be an indispensable aid if it is tailored to the needs of the respective risk and crisis management phases and the various users.

During an ISCRAM 2015 workshop experts of the risk and crisis management community meet software architects and engineers of the geospatial domain. The objective is to investigate use cases and map them to capabilities of an underlying geospatial ICT infrastructure. The workshop shall launch a sustainable discussion between ISCRAM and the Open Geospatial Consortium (OGC), especially its Emergency and Disaster Management (EDM) domain working group, beyond ISCRAM 2015.

Keywords

Open Geospatial Consortium (OGC), ICT, geospatial services, service-oriented analysis and design, scenarios, use cases.

MOTIVATION

Efficient crisis response and management requires well-informed actors and stakeholders and effective means for communication and policy enforcement. This is, on the one hand, a question of good and well-organized prevention and risk management as part of a prepared society. On the other hand, it is a question of how today's information and communication technology (ICT) capabilities may be exploited. A secure and dependable geospatial ICT infrastructure may be an indispensable aid if it is tailored to the needs of the respective risk and crisis management phases and the various users.

The challenge is to provide and maintain an adequate ICT infrastructure such that the real needs of users are fulfilled in a crisis situation. User requirements need to be well understood. This issue starts with the questions who the users are, i.e. which actor roles may be expected. The information needs of a citizen differ from those of a crisis manager, not only in terms of detail but also in terms of language and notation. However, there is good news. Experience shows that some major requirements on such infrastructures are similar despite different types of risks, regions and cultures. There is a core set of requirements that has to be basically fulfilled by a generic infrastructure. Specific requirements may then be realized on this basis in terms of dedicated software applications, e.g. smartphone apps for mobile devices tailored for a specific user group such as tourists. The challenge is to find the set of basic functions and properties. Ideally, such an infrastructure is relying upon internationally agreed ICT standards such that interoperability and portability of software applications is considered by design.

During an ISCRAM 2015 workshop experts of the risk and crisis management community meet software architects and engineers of the geospatial domain. The

idea is to discuss user requirements described by experts in terms of semi-structured use cases and map them to geospatial ICT capabilities (services and information models) as offered by the Open Geospatial Consortium (OGC). It shall launch a discussion forum between ISCRAM and the OGC, especially its Emergency and Disaster Management (EDM) domain working group.

METHODOLOGY FOR SERVICE-ORIENTED ANALYSIS

Agility in software and service engineering usually needs to encompass the requirements analysis phase. The reason is that, only in rare cases, the requirements are fully available and fixed when software design and developments starts. In contrary, especially in the domain of environmental information systems, requirements analysis is an agile process including a multi-step dialogue between the user(s), the stakeholders and the software architects that know about the technological capabilities and constraints and may also estimate the effort to realize the expectations of the user. The resulting discussion often leads to reconsiderations and/or refinements of the user requirements. If multiple users of one or even multiple organizations are involved, such dialogues are usually carried out in requirements analysis workshops facilitated by experienced systems analysts or architects. The crucial aspects are a solid methodology underpinning this process as well as an associated flexible documentation of the requirements during this process, also taking into account capabilities and constraints of underlying geospatial architectures [3]. The workshop relies upon Web-based collaborative tool that supports the documentation according to the SERVUS design methodology [2].

The SERVUS design methodology describes individual design activities interconnected by a common modelling environment. It follows a resource-oriented approach according to the Representational State Transfer (REST) architectural style [4]. Hereby, a resource is considered to be an information object that is uniquely identified, may be represented in one or more representational forms (e.g. as a diagram, XML document or a map layer) and support resource methods that are taken from a limited set of operations whose semantics are well-known (uniform interface). A resource has own characteristics (attributes) and is linked to other resources forming a resource network.

Furthermore, resource descriptions may refer to concepts of the domain model (design ontology) using the principle of semantic annotation, yielding so-called semantic resources

Use case models describe the behavior of a system [5] whereby “a use case is a sequence of actions performed by the system to yield an observable result that is typically of value for one or more actors or other stakeholders of the system”.

When designing a risk and disaster management and information system, a use case expresses the functional, informational and qualitative requirements of a user (i.e. an actor or a stakeholder) with respect to the system. It is essential that the degree of abstraction and formalism, and the language should be such that it is adequate to the domain of expertise of the users. To serve as an agreement, it shall be understandable to the users but also precise enough. Often this means that use cases are specified in a non-technical way, normally achieved using plain text in natural language. However, in order to reduce the ambiguities and impreciseness of descriptions in natural language, a structured textual description is preferred, i.e. the use case description may be structured according to a given template, e.g. an application form associated with code lists.

The SERVUS design methodology [6] recommends a semi-formal description of use cases, e.g. according to the template proposed by Cockburn [1], but extends it in order to include references to requested resources, e.g. a time-series of water gauge values represented as a diagram. Furthermore, it may be accompanied by a UML use case diagram as an option.

The use case meta-model describes all the element types in a use case model and its relationships to each other. In addition to use cases as main element types, the SERVUS use case meta-model comprises the following element types:

- **actors:** describes the roles of users that initiate use cases.
- **test cases:** describes a possible instantiation of a use case that is decisive for the system test with respect to this use case.
- **requirements:** describe functions of the system under design that may support the execution of a use case. For the ISCRAM workshop, the requirements comprise the geospatial services as described below.

- **information resources:** describes the information elements including its basic operations (create, read, update, delete) that are required to carry out the use case.

Each element type has its own structure and template, i.e. its own set of text elements. There are the following relations between these element types: **use cases (UC)** are linked to **actors**, to other use cases, to **test cases**, to **requirements** and **information resources**. These relations are illustrated in Fig. 1.

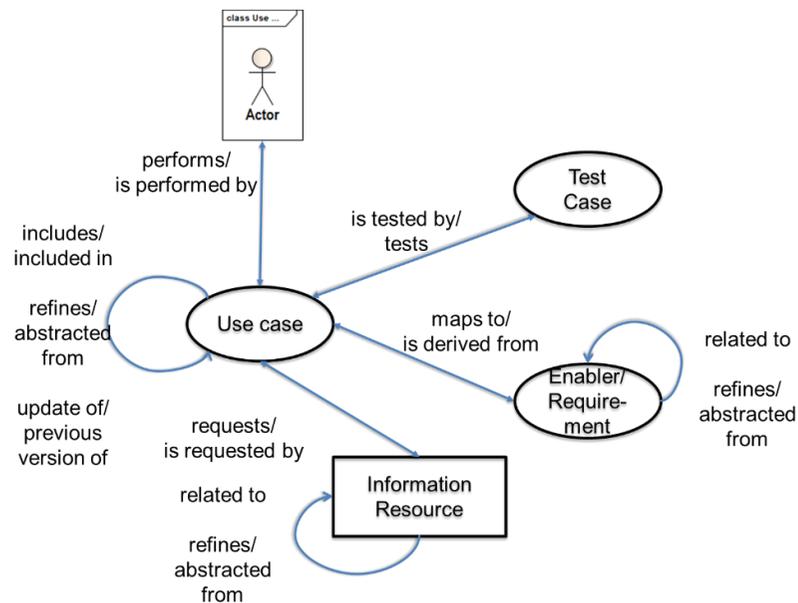


Fig. 1. Relationships between Use Cases, Requirements, Actors and Information Resources

During the ISCRAM workshop, the SERVUS use case tool allows the users to work in parallel in a Web-based collaborative and distributed manner. The tool supports an agile approach, i.e. use cases and the other elements in the model may

be iteratively specified which allows the users to refine and change them according to the knowledge that is gained in the analysis and design process of the individual scenarios (see below) during the workshop.

The result of the workshop is available for the ISCRAM community and may be complemented and refined in other contexts, e.g. other conferences, research or development projects.

OPEN GEOSPATIAL CONSORTIUM (OGC)

The OGC (<http://www.opengeospatial.org/>) is an international industry consortium of over 500 companies, government agencies and universities participating in a consensus process to develop publicly available interface standards. OGC standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services and mainstream IT. The standards developed by the OGC have been applied successfully in a variety of domains, such as aviation, built environment, defense and intelligence, or of particular interest here, emergency response and disaster management. All standards are released to the public free of charge.

Through a number of liaisons, OGC standards are implemented or used in other standardization organizations, e.g. ISO. The OGC has four different programs working actively together to ensure that standards released to the public meet all requirements defined by data producers and consumers.

1. Standards development takes place in the standards program, where all member organizations jointly develop the specifications in a consensus driven way. The requirements on these standards as brought into the process by the members participating in a particular standards development thread. Each member has the right to participate in any of those threads and by joining the standards working group.
2. The interoperability program tests new technologies and serves as the innovation hub for new standards of revisions on existing standards. The program features various activities, from early brainstorming sessions to plug fests, where existing implementations are tested in a hands-on

environment with the goal to verify and improve interoperability between different vendors' products.

3. The compliance and certification program delivers testing environments that help vendors to test compliance of their products. OGC's Outreach and Community Adoption Program promotes global advancement of geoprocessing interoperability through education, awareness building and strategic relationships.

Jointly, those four programs ensure that standards are based on a wide set of requirements coming from various domains, sufficiently stress-tested in real world situations, certified of the shelf products available for customers.

GEOSPATIAL SERVICES

The OGC has developed a set of abstract specifications that provide a modeling perspective of geospatial entities and information models. Those abstract specifications are implemented in a number of domain-independent Web service interfaces using various transport encodings and serializations. The development of domain-specific application profiles of data models and encodings allows considering domain-particularities and specific requirements set within a domain. This principle features a high level of interoperability within a domain as well as beyond the border to other domains. In the disaster management and emergency response domain, it allows to exchange information between first responders, command centers, hospitals, fire and police teams, or the public and supports the efficient integration of additional datasets without time-consuming and error prone transformation between data formats.

A variety of geospatial service interfaces (see the major ones in Fig. 2) and data encodings have been developed. They support catalog services for service and data discovery (CSW), mapping services to display imagery maps or map tiles (WMS), transactional vector data to read and write vector data (WFS), dedicated services for sensor observations (SOS) and sensor-related alerts (SAS), coverage services to provide raster data (WCS), and processing services to include data processing workflows (WPS), or sensor planning (SPS).

Data models and encodings such as the Geography Markup Language (GML), CityGML, KML, NetCDF-CF or Observation & Measurement (O&M) allow efficient and schema conformant serializations of geospatial data. Those services are well designed to support disaster management and emergency support scenarios, though those services require Internet connectivity to provide optimal performance, a luxury that is not always available in case of a larger emergency. To manage those situations of intermitted connectivity, the OGC has developed standards that support offline usage and subsequent synchronization and are adapted to the specific requirements of mobile devices experiencing connectivity issues.

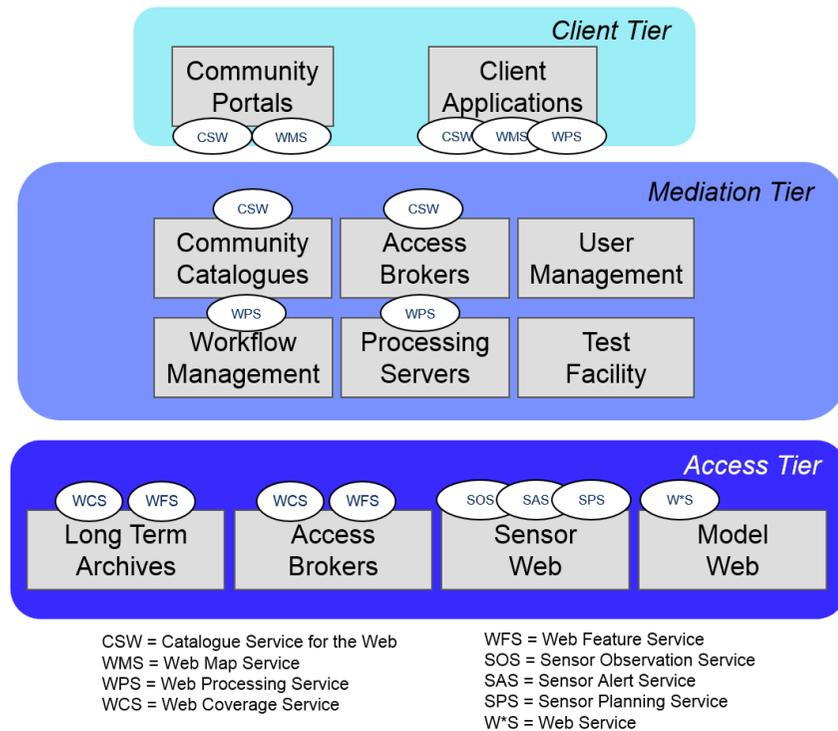


Fig. 2: Major OGC Geospatial Services

One of the most important standards in this context is GeoPackage, a container format that allows taking geospatial data, received from an enterprise database or a number of Web services into the field. GeoPackages can be created on the fly using Web Processing Services (WPS). Those Web processing services receive context documents, which include detailed definitions and links to (potentially distributed) data sets or data serving services, such as e.g. Web Feature Services or Web Map Tile services. Data is packed into a standardized SQLite-based GeoPackage container and taken to the area of operation.

The OGC currently works on peer-to-peer synchronization, peer-to-enterprise database and enterprise database to enterprise database synchronization. Once completed, emergency response teams can set up various connection types and are enabled to synchronize data in the field, by which data can be exchanged even though no network is available. Other current work items address the integration of social media. Robust and well-tested services are currently under investigation to support mapping between geospatial professional applications and platforms such as Twitter, Facebook, or Instagram.

Further on, the existing services and encodings are getting complemented with new services, architectural patterns, and encodings coming from the Semantic Web community. The goal is to make data available in a way that others can understand without ambiguity what was observed where and under what conditions. Eventually, linking data sets to other data allows understanding the context of data. It allows understanding when and where things changed and helps identifying triggers or events that caused emergencies. It allows integrating all data sets that are relevant to understand a specific situation or the developments that led to the situation and facilitates efficient recovery phase activities and risk prevention and mitigation measures.

USER SCENARIOS

As part of the workshop, four user scenarios are discussed in detail. They differ in terms of their geographical scope, the covered risk management phase and the disaster type being investigated. This diversity is crucial to cover a representative portion of the end user needs. The following table provides an overview.

No	Title	Disaster Type	Risk Management Phase	Geographical Scope
1	Predictive models vis-a-vis responders efficacy	Earthquake	Response	USA and beyond
2	Rapid response tools for operational management of seismic crisis on a border area: case-study of the Pyrenees	Earthquake	Response	Pyrenees, France

3	Real-time global modeling in new research laboratory for world-wide decision support	Flood/storm surge	Early Warning	Global
4	Collaboration during a Flooding Event with Cascading Effects	Flood	all	Global

No 1.: This scenario is motivated by the fact that major issues revolve around the response to crisis events (here: earthquake) rather than the event itself. Modern technology has provided citizens with predictive models that deliver some lead time prior to the event in many cases. The needs of stakeholders in earthquake identification and response vary based on the time in the continuum of the event. That is, those reporting the initial seismological data must provide timely accurate data. Subsequent responders to the inevitable must activate a model that maximizes efficiency and minimizes losses. Despite this predictive accuracy for earthquakes the quake itself is inevitable. Therefore, there must be a guide of sorts to organize a well choreographed efficient response that minimizes the human and economic losses in the wake of such an occurrence. The United States created a template that is used as a national model for natural and man-made disasters. This post-event scenario turns on the implementation and subsequent outcome evaluation to assess the efficacy of invoking such plans outside of the US. It may be that they provide responders with a clear picture of their roles prior to an event, and protects citizens while diminishing the losses created by the event. Moreover, if such a template were to become an international universal model it would allow an exchange of roles in a global crisis without jeopardizing the efficacy of the interventions after an earthquake and other disasters requiring immediate interventions. The research question is how geospatial service may support the implementation of such models.

No 2.: The Pyrenees constitute one of the most earthquake-prone regions of mainland France and Spain. At the “observational” level, the Pyrenean region is monitored by several seismological networks on both sides of the border, counting in total around 120 seismic stations (of different types). Thanks to a progressive

decrease of constraints associated to real-time seismology, a growing proportion of these stations are progressively called to evolve toward real-time data transmission. Each country has its own civil protection organization as well as specific earthquake crisis plans. However, big earthquakes in the Pyrenees can impact both borders. Moreover, systemic cross-border interactions are of multiple nature (transport network, energy lifelines, hospitals access, cross-border populations, etc.).

Experience of past earthquakes as well as "earthquake" civil-protection's exercises underlines the need for crisis managers to have at their disposal rapid-response tools able to assess consequences caused by earthquakes, even for moderate events. Further on, there is a need to take into account operational requirements related to the management of seismic crisis. Work is being performed in order to provide the authorities with a quick assessment of the human tolls (potential victims or damages, needs for shelters) that may control their actions, structured within reports dedicated to civil-protection teams. The research question tackles the specificity of geospatial service requirements in such cross-national environments.

No. 3.: This scenario describes the needs of real-time global modeling in a new research laboratory for world-wide decision support. During crisis and disaster situations, important and quick decisions must be made that can depend on access to large amounts of data. At times like this, access to all the relevant data and tailored visualizations is crucial. The facility hosts the research flood and storm surge forecasting systems GLOFFIS (Global Flood Forecasting Information System) and GLOSSIS (Global Storm Surge Information System) for global/continental/regional scale. One example is the rapid modelling of hurricane or typhoon situations, where detailed maps of possible impact are required by EU/UNDP emergency support teams or NGO like CORAID, Red Cross. The rapid modelling is using available Open Data and satellite information. The research question is how open geospatial services may improve the data acquisition and information processing capabilities of the research laboratory.

No. 4: This scenario covers the collaboration during a flooding event with Cascading Effects. Its purpose is to show how sharing of geo-spatial information between the stakeholders leads to new capabilities for decision making. All four

phases of the crisis management process are covered: prevention, preparation, reaction and recovery. The expected benefit is to prove that only the improved situation awareness and collaboration achieved by geo-spatial information sharing allows getting back from a re-active into a pro-active role of managing the disaster. Several actors are involved: civil protection (crisis staff), fire service, citizens, city administration, meteorological institute, hydrological institute and a power company. The research question to tackle is how the diverse requirements of these different actors may be mapped to common geospatial service capabilities.

CONCLUSION

The result of the workshop is a structured documentation of the user scenarios in terms of use cases made publicly available via a Web-based collaborative tool by Fraunhofer IOSB. Further on, these use cases are mapped to requirements and capabilities of OGC-based geospatial service. Following this process, it is envisaged that gaps in the OGC standardization are detected and documented as well. These gaps provide essential input to other multi-disciplinary communities beyond ISCRAM 2015, e.g. OGC's Emergency and Disaster Management (EDM) domain working group. The results will also be fed into other committees seeking for standardization gaps, e.g. the newly formed Web of Things (WoT) Interest Group of the World Wide Web Consortium (W3C).

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REFERENCES

1. Cockburn, A. Writing Effective Use Cases. ISBN-13: 9780201702255. Addison-Wesley, 2001.
2. Usländer, T.: Service-oriented Design of Environmental Information Systems. PhD thesis of the Karlsruhe Institute of Technology (KIT), KIT Scientific Publishing. ISBN 978-3-86644-499-7, 2010. <http://digbib.ubka.uni-karlsruhe.de/volltexte/1000016721>
3. Usländer, T., Denzer, R.: Requirements and Open Architecture for Environmental Risk Management Information Systems. Chapter 15 of Van de Walle, B., Turoff, M. and Hiltz, S.R. (eds.): Information Systems for Emergency Management. In the Advances in Management Information Systems monograph series (Editor-in-Chief: Vladimir Zwass). Armonk, NY: M.E. Sharpe Inc., ISBN 978-0-7656-2134-4, 2009.
4. Fielding, R.T.: Architectural Styles and the Design of Network-Based Software Architectures. Doctoral dissertation, University of California, Irvine, 2000. <http://www.ics.uci.edu/~fielding/pubs/dissertation/top.htm>
5. Jacobson, I. and Ng, P.-W.: Aspect-Oriented Software Development with Use Cases. The Addison-Wesley Object Technology Series, ISBN 0-321-26888-1, 2005.
6. Usländer, T., Batz, T.: How to Analyse User Requirements for Service-Oriented Environmental Information Systems. In: Proceedings of the ISESS 2011, Brno, Czech Republic, pp. 161-168, Springer Verlag, 2011.