Solving Interoperability Issues in Cross Border Emergency Operations

Frederik Schütte
antwortING Ingenieurbüro PartG, Germany
schuette@antwortING.de

Rubén Casado
Treelogic, Spain
ruben.casado@treelogic.com

Emilio Rubiera
Fundación CTIC, Spain
emilio.rubiera@fundacionctic.org

ABSTRACT

This paper describes the work that is being done within the EU research project DISASTER to solve interoperability issues in cross-border emergency operations by applying a technical solution that is able to create a common operational picture. To that end a twofold solution is proposed: the development of a common and modular ontology shared by all the stakeholders taking into account different countries cultural, linguistic and legal issues. And, from that point, bearing in mind that most legacy EMSs (Emergency Management Systems) rely on Service-Oriented-Architectures (SOA), the implementation of transparent SOA mediation algorithms compliant with current data formats and existing solutions. That way, a mediation solution is provided by the DISASTER Mediator, which plays the role of gateway for each EMS enabling a communication based in Web Services. In order to avoid a misunderstanding of shared information it is necessary to create a solution that offers more than a plain translation of terms but rather a concept mediation so the corresponding user is able to understand the situation in its own framework of reference.

Keywords

Interoperability, Ontology, Mediation, SOA, Emergency Operation, Cross-Border, International.

INTRODUCTION AND MOTIVATION

Emergency management involves several actors that must interact in order to prevent a risk or to coordinate their activities to react to hazardous situations. This interaction mainly implies the interchange of information to provide a quick and integrated response to the threatened event. Sharing information and coordination between international workforces, dealing with a large amount of information in a highly dynamic environment, is one of the most challenging tasks in emergency management.

In order to manage and share critical information, dedicated ICT systems, usually known either as Emergency Management Systems (EMS) or Crisis Information Management Systems (CIMS), have emerged. In the Member States of the EU, each stakeholder has deployed its own system of command, control and communication. As a direct result of this situation, EMSs and information data models and formats are invariably incompatible with each other, meaning that cooperation between emergency forces becomes almost impossible in many regions. Moreover, in an international European context, the situation with regard to the EMS-to-EMS exchange of information provides a number of challenges, considering not only technical interoperability (data formats, models and communication protocols), but also diversity in language (27 member states, with more than 23 official languages), background and cultural particularities (e.g.: metric system), methodology or structure (diversity of organizational structures starting at local level), legal issues (different regulation, complex legal landscape), or data representation (inconsistent color codes, different graphical symbol sets), among others.

Given the above issues, it is necessary a technical solution that, on the one hand, must integrate the existing EMSs in a reliable, secure, and user-friendly manner. On the other hand, such solution has to achieve the goal of sharing semantically unambiguous information basis across organizations. Those are the challenges of the EU funded project DISASTER [1]. The novel features and contributions of the work presented in this paper are as follows:

- EMERGEL, a common and modular ontology to gather all the stakeholders' knowledge in a unique and flexible data model considering different countries cultural, linguistic and legal issues.
- A Web Service-based architecture to achieve mediated communication between independent EMSs.
- An early validation of the proposed solution through an actual, real scenario.

The rest of the paper is structured as follows. Section 2 addresses the requirements (both functional and non-functional) from the users point of view. Section 3 presents the ontology-based solution to achieve the semantic integration of resources. Section 4 defines the architecture of the DISASTER implementation and also presents a developed proof of concept of a concrete scenario. Finally, Section 5 concludes the paper and outlines the future work.

USER REQUIREMENTS FOR SEAMLESS INFORMATION EXCHANGE IN CROSS-BORDER EMERGENCY OPERATIONS

The user in terms of this paper can be stated the silver command or tactical command level of a rescue operation. These users will constantly be using the DISASTER interoperability solution in order to exchange data with other sections or other organizations within the same operation following existing models [2]. The following requirements were identified by interviews as well as the authors own experience and reinforced by survey results.

Since the DISASTER project aims to create an interoperability solution for the emergency management sector the issues connected with and to be addressed during the development need to be split into technical issues that need to be solved within the software and non-technical issues that need to be solved with the software.

The technical issues that need to be solved are the keystone of the DISASTER project. It can be assumed that, if these issues are not solved within the software, the DISASTER solution will not be able to solve the non-technical issues. The main areas of interest here are format and protocol as well as data representation. Format and protocol issues, or in other words syntactical interoperability, are the basis of all communication between systems. This communication can take place either by standards or by message mapping to convert the data. It is necessary to identify in which cases which solution is suitable. However message mapping might be the more suitable solution for complex concepts that need to be transferred like units or vehicle types. These data needs serious interpretation by the user to be understood and put into a correct context and reference frame [3]. Therefore a plain translation of terms is not suitable. Rather, these data needs to be translated also in terms of underlying concepts. The tactical and technical operational value concept offers a possible solution for this as the German DV 100 [4] offers a comprehensive approach to completely describe a situation.

Understanding of the situation comes with a suitable representation of the transferred data. The most comprehensive form to represent relevant data in a rescue operation is the situational map, which can be seen as the concrete form of the framework of reference of a particular operation. Therefore the DISASTER solution should be able to transfer the needed data to create such a situational map. In this context geo-referencing is important for the system to correctly place units and other items on the map if the map is created by the system out of different pieces of information. However, very exact geo-referencing is of no great importance for understanding the situation according to experts in incident command. Understanding of a situation needs to be created by transferring the underlying concept of the data to the receiver. It is necessary to do this in a very structured way so that no information is erased or created without recognizing it. Translation tools as mentioned above can help to achieve this goal. However, it is necessary to know that most of these issues can only be solved by technical means. In contrast to the technical issues this type of issues can be summarized as semantic issues.

The last aspects to mention are cultural and organizational differences between the organizations that like to exchange information. While cultural differences hinder the understanding of the information since the concepts and the framework of reference is different, the organizational differences might hinder the very data exchange. Cultural differences can be solved by implementing solutions for the semantic issues mentioned above. This means the more different the (EMS) culture, the more translation work needs to be done. In contrast, organizational issues need to be solved before an interoperability solution can be implemented. Therefore it is necessary to provide a guideline of how to implement the DISASTER solution and which changes need to be done to prepare implementation. The final goal of the DISASTER solution is to create understanding for a situation by different stakeholders. Therefore the non-technical interoperability issues are of great importance.

INTEROPERABILITY SOLUTIONS FOR MEDIATION AND STRUCTURING THE EMS DOMAIN

One of the main goals of the DISASTER project is the development of a common and modular ontology capable of being exploited by all the stakeholders dealing with a given emergency situation. This ontology is designed to gather all the stakeholders' knowledge in a unique and flexible data model considering different countries cultural, linguistic and legal issues. The ontology takes into consideration all the knowledge already available in some of the EMSs used in Europe, and some deep analysis of EMSs is provided by domain-specialist partners of the DISASTER project to help the ontology designers understanding the domain.

The DISASTER project is currently in the first steps of implementing the EMERGEL ontology[1], from which the core and transversal modules are just partially published. This ontology is a key element of the DISASTER project. EMERGEL stands for EMERGency ELements and, being more specific, it is a vocabulary that takes into account questions like:

- *What:* The ontology interprets a disaster as a kind of event. Therefore, two upper-level classes are hierarchically introduced: Disaster as subclass of Event. Furthermore, the ontology builds upon existing disaster classifications widely used in security domains, such as insurance, freight transport and critical infrastructures (ports, airports, etc.). After studied and analyzed, these classifications have been adapted and merged to fit the modeling requirements identified in a set of competency questions defined and discussed with the partners of the DISASTER project.
- *Why:* Events are susceptible to cause other events. A simple landing operation of a plane can lead to a disaster like an airplane crash in an airport. Additionally, this accident may have direct and collateral consequences as a fire, chained explosions, a chemical accident in a neighbor industrial facility, a full airport block, etc. The EMERGEL ontology has been defined also to semantically capture the causality chain between the diverse events in a given disaster.
- *Who:* Many agents can take part and can be considered in a disaster. To this end, the DISASTER ontology reuses other Semantic Web vocabularies to capture all the possibilities within the different agents involved in an emergency situation. For instance, EMERGEL takes into account that a given fireman can become a victim depending of the context and the moment, or the fact that a specific firefighter can play different roles, as "forest firefighter" and "group manager" in the same time. In addition, many stakeholders are defined in the vocabulary: firemen, police, army, etc.
- *Where and when:* The proper spatio-temporal contextualization of a disaster is crucial to ensure successful information exchange among stakeholders. The ontology provides means to temporally describe a crisis situation in RDF. This is a critical problem as information changes over time, and in particular, with respect to space. For instance, the damaged surface due to a forest fire is not the same at the beginning of the conflagration than two days afterwards. DISASTER approach is based on a 4D (four-dimensionalism) view of the reality, sometimes called a perdurantist perspective.

But the DISASTER ontology will not limit to face the aforementioned questions. It will also address another complex issues, as it is the case of classifications, e. g. map symbol sets, specific domain terminologies, etc., so different from country to country and therefore pertinent when dealing with emergency situations located in borders where stakeholders from different countries or cultures are involved.

Most of the geospatial classifications provide map symbols. These icons are used in data visualization to understand the cartography of the map, i.e., what is the kind of feature present at a given location. Map symbols are used from the origins of cartography and there exist a huge diversity of collections based on cultural and historical reasons.

The DISASTER ontology uses the SKOS [5] vocabulary to easily capture collections (map symbols, product classifications, etc.), the subjacent concepts and hierarchies. This way, a reuse of all the legacy classification systems as SKOS taxonomies is ensured in order to share a common knowledge structure. EMERGEL, by means of the mappings module, captures domain-expert knowledge, finding the match between classifications and all that can be consumed by the mediation component that offers classification translations capabilities.

Once the domain is formalized by the ontology, and having in mind that most legacy EMS are based on Service-Oriented Architectures (SOA) that compile information from distributed and specialized systems (e.g. Geographic Information Systems), the interoperability information burden will be addressed by means of transparent SOA mediation algorithms compliant with current data formats and existing solutions. This architecture design is described in the following section.

[1] http://purl.org/emergel

TECHNICAL SOLUTION USING A SCENARIO BASED APPROACH

This section presents the current version of the technical architecture devised to achieve the goals of the DISASTER project. The whole solution is widely influenced by actual scenarios; one of them has been used to evaluate the current version of the proposed solution.

Technical architecture

The DISASTER architecture follows the Service Oriented Architecture (SOA) approach. The term SOA refers to service creation, interaction, presentation, and integration infrastructure capabilities to build business-level software based on reusable components. The new layer of abstraction introduced with service orientation now presents a solution to bridge the communication gap between IT developers and experts using these services, introducing a new business process driven approach. For disaster management, this separation of concerns between definition and description of business processes and its actual implementation in form of computational services bares the potential to give consideration to the functional heterogeneity of partners involved. Public authorities or other institutions in disaster management are able to understand the semantics of the services and can therefore integrate them in their decision making process, while scientists and technicians provide and administer these components. As an architectural concept, SOA permits multiple approaches for the realization and deployment of an IT system that has been designed and built around its service-based principles. The DISASTER solution adopts a specific technology that, arguably, has the most significant academic and industrial visibility and attraction, and that is Web Services (WS). A key aspect of WS is the use of an open, standard-based approach in which every WS specification is eventually standardized by an industry-wide organization such as W3C [6] or OASIS [7]. This approach focused on the interoperability of systems perfectly fit with the DISASTER´s goals.

The DISASTER architecture relies on two main types of elements as shown in Figure 1. DISASTER Core is the kernel of the architecture and provides a set of functionalities shared by all involved participants. This element is also in charge of managing communications between existing DISASTER mediators taking the role of directory service. DISASTER Mediator plays the role of gateway for each EMS connected to the DISASTER ecosystem. This element connects a concrete EMS to other EMS and existing resources but getting such exchange of information in a local context. In other words, the DISASTER Mediator allows an EMS to use external information but transformed according to its own protocol, format, cultural and linguistic characteristics. In this way, the DISASTER architecture is defined as a network of DISASTER Mediators with a central DISASTER Core.

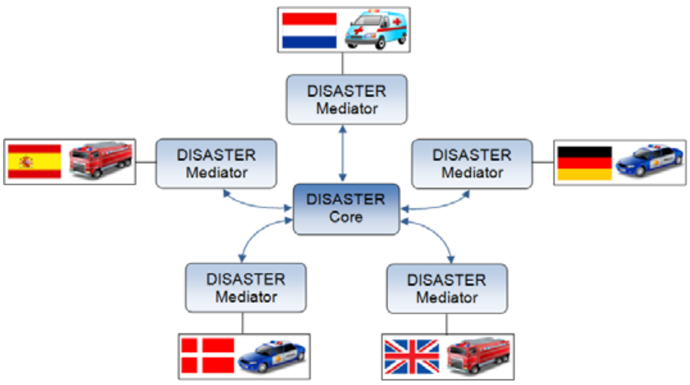

Figure 1. The DISASTER design roles

The border fire scenario

In order to provide better understanding of the context, a mediation scenario was chosen based on a real incident. The scenario, illustrated in Figure 2, is a moor fire on both sides of the national border between Germany and the Netherlands. Fire brigades of both countries are involved. The fire brigade professionals from both countries want to share a common operational picture, which in theory is possible. All professionals involved rely on having their map presented in their own local context. In the case of this scenario, the same data should be presented in two local contexts. In particular, the German brigade creates and keeps a map up to date with the situation on the German side. Such information has to be used by the Dutch brigade. As shown in Figure 2, each response team uses a concrete set of icons to define the fire situation. Besides the cultural difference, some technical issues also have to be addressed. German brigade publishes the map in a Web Feature Server (WFS). On the other hand, the Dutch emergency system only accepts the Web Map Service (WMS) based servers. It implies different levels of mediation:

- Cultural mediation: To use different icons to represent the same concept
- Protocol mediation: To allow using WMS protocol when WFS is expected
- Format mediation: To translate GML text information into valid PNG map images

This scenario has been developed as proof of concept in order to validate the proposed DISASTER solution [8]. A plugin was developed to an existing open source map editor in order to emulate the German EMS. In the Dutch side, the actual LCMS software was used to see the outcome of the mediation process. The mediators of both German and Dutch side were developed. Also a first approach to the Disaster Core was developed. The successful results were shown in the 8th Gi4DM [9] to obtain the experts´ feedback. The results showed the viability of the proposed solution.

As mentioned before, the definition of the technical architecture is a work-in-progress task. The current state of the research is focused on GIS data, but, as new scenarios are defined, the architecture will be upgraded to meet the new technical requirements.

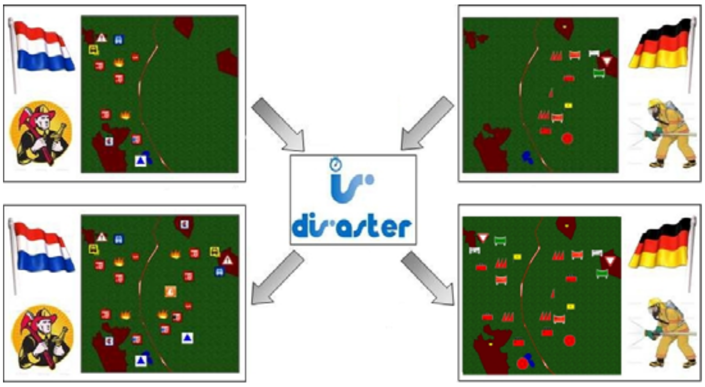

Figure Border fire scenario and DISASTER assistance

CONCLUSION AND FUTURE WORK

DISASTER aims to provide a mechanism so that different EMS can interoperate during the management of crisis scenarios. The solution is based on two main concepts: (i) the use of semantic technologies supporting the goal of shared and semantically unambiguous information basis across organizations, and (ii), the SOA paradigm to allow the collaboration between systems of different nature. The devised architecture has been validated through the development of a proof of concept and tested by experts showing the viability of the proposed solution. DISASTER is an on-going project so here we have presented the current state of research regarding the ontology definition and technical architecture design. Future work includes, among others, the integration of other kind of information such as the P2000 network and extension of the scope of the proof of concept for further validation and improvement of the proposed solution using actual crisis scenarios.

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