EDXL-RESCUER ontology: an update based on Faceted Taxonomy approach

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Abstract. *This paper describes an ontology created for the RESCUER[1] (Reliable and Smart Crowdsourcing Solution for Emergency and Crisis Management), a project funded by the European Union and the Brazilian Ministry of Science, Technology and Innovation. RESCUER uses crowdsourcing information for supporting Industrial Parks (InPa) and Security Forces during an emergency situation. The proposal, EDXL-RESCUER ontology, is based on EDXL (Emergency Data Exchange Language), and it aims to be the RESCUER conceptual model related to the coordinating and exchanging of information with legacy systems. The ontology was evaluated with end-users during a workshop and the results show that EDXL-RESCUER is adequate for Emergency and Crisis domain in InPa and Security forces contexts. Specifically, this paper presents an update of EDXL-RESCUER ontology based on a faceted taxonomy approach.*

Resumo. *Este artigo descreve uma ontologia criada para o RESCUER (Reliable and Smart Crowdsourcing Solution for Emergency and Crisis Management), um projeto patrocinado pela União Européia e pelo Ministério de Ciência, Tecnologia e Inovação do Brasil. O RESCUER usa informação do público para apoiar Parques Industriais e Forças de Segurança durante uma emergência. A ontologia proposta, EDXL-RESCUER, é baseada no EDXL (Emergency Data Exchange Language) e pretende ser o modelo conceitual do RESCUER relacionado à coordenação e troca de informação com os sistemas legados. A ontologia foi avaliada com usuários finais durante um workshop, e os resultados mostram que EDXL-RESCUER é adequada para o domínio de Crises e Emergências nos contextos de Parques Industrias e Forças de Segurança. Especificamente, este artigo apresenta uma atualização da EDXL-RESCUER baseada em uma abordagem de taxinomia facetada.*

1. Introduction

Crowdsourcing information (information that comes from different sources: people affected by the incident, eyewitnesses, security forces and others) is becoming widely used as a source of knowledge and solutions for different problems

[1]http://www.rescuer-project.org/

[Beriwal and Cochran 2013][Besaleva et al. 2013][Eccher et al. 2013]. This paper is part of a research project for developing a crowdsourcing solution for emergency management, the RESCUER project [Villela et al. 2013]. RESCUER intends to provide command centers with real-time contextual information related to the emergency through the collection, combination and aggregation of crowdsourcing information, and to support announcements about the emergencies tailored to different audiences (e.g. authorities, affected community and public).

The RESCUER project encompasses four main components as shown in Figure 1:

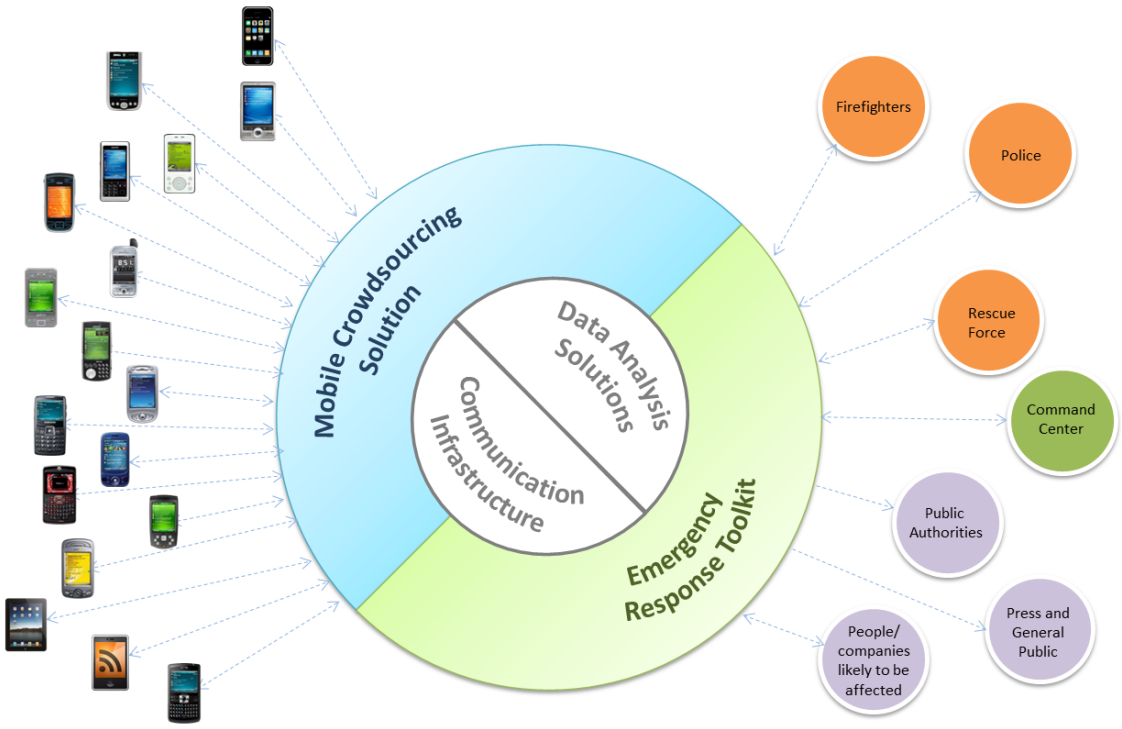

Figure 1. Conceptual model of RESCUER [Villela et al. 2013]

- Mobile Crowdsourcing Solution: support eyewitnesses communication with official first responders (police, firefighters, etc.) and command and control centers. The crowd can send information in text, image and video formats. It comprises a set of mobile applications tailored to different platforms and devices;
- Data Analysis Solutions: composed of the algorithms that will process and filter the data in order to extract the required information;
- Communication Infrastructure: offers the needed equipment in order to allow the information to flow between the stakeholders; and
- Emergency Response Toolkit: a set of solutions to manage the analyzed crowdsourcing information and to present them to the command and control center using adequate visualization metaphors.

The InPa (Industrial Park) Brazilian partner is the COFIC [COFIC 2009] (Industrial Development Committee of Camaçari), which manages security simulations and deals with legal procedures and media. The Security Forces are represented by the CICC

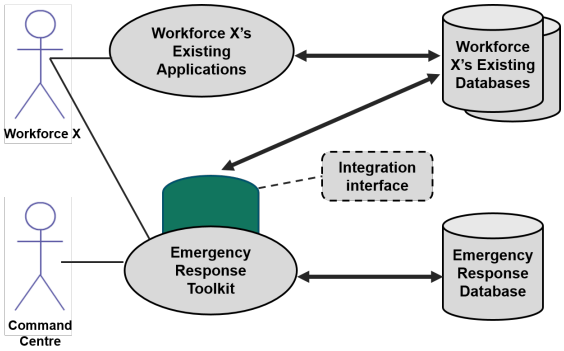

Figure 2. Ontology's role in RESCUER system [Villela et al. 2013]

(Integrated Command and Control Centre) in Brazil and by the FIRESERV[2] in Europe. These partners have contributed to the project with expertise and knowledge on how command and control centers operate in large-scale events, as well as in industrial areas. In this context, interoperability between the RESCUER project and legacy systems' partners is critical for the success of the solution. For the purpose of semantic and seamless integration of legacy systems with RESCUER, the use of ontologies seems to be most suitable, since they offer a basis for a shared and well-formed specification of a particular domain. Thefore, in this proposal, an ontology is presented that will comprise the RESCUER conceptual model related to the coordinating and exchanging of information with legacy systems.

From this perspective, the use of a well-referenced standard by the scientific community, the EDXL [OASIS 2014] – Emergency Data eXchange Language-, as a basis for the new ontology was chosen. EDXL is a common standard that is accepted and used in several applications dealing with disaster management [Genc et al. 2013] [Kilgore et al. 2013]. It is composed of several packages – the current standard version has seven packages, each of which is related to a particular aspect of the emergency domain. A subset of EDXL has been chosen in order to specify the EDXL-RESCUER ontology (details of this process are discussed in section 3). The formalization of the first version of the ontology can be found in our previous paper [Barros et al. 2015]. As an incremental approach is being used, in this paper an update of EDXL-RESCUER ontology based on faceted taxonomy formalization is presented

The Figure 2 shows the ontology-based integration module (green box) in RESCUER architecture, specifically in its interaction with ERTK. This module will have three main parts: 1) the EDXL-RESCUER that works like a global ontology; 2) the database schemas from ERTK and legacy systems involved; 3) mappings between the ontology and the local schemas.

The evaluation of EDXL-RESCUER ontology was performed in two steps:

1. Validation through competency questions - questions that an ontology should be able to answer. This validation is based on a well know method in Ontology Engineering (for further information see the TOronto Virtual Enterprise (TOVE) [Grüninger and Fox 1995] and the METHONTOLOGY

[2]http://www.fireserv.at/

[Fernández-López et al. 1997]).

2. Brainstorming with potential end users for validating the ontology terms. The results show that the EDXL-RESCUER ontology is suitable for specific goals proposed in RESCUER project.

This paper is structured as follows: in the Related Works section, research projects related to emergency, ontology and interoperability are presented. Next, an EDXL-RESCUER ontology and its update based on faceted taxonomy approach is presented. In the Evaluation section the workshop with end-users is described and the results derived are presented; finally, a conclusion of the work done and future developments are presented.

2. Related Works

Ontology has been used on several domains in order to solve interoperability problems, including emergency and crisis domain [Eccher et al. 2013] [Mescherin et al. 2013] [Shah et al. 2013] [Shan et al. 2012] [Xiao et al. 2013].

Based on review of related literature, one project stood out: the DISASTER (Data Interoperability Solution at Stakeholders Emergency Reaction) project [Azcona 2013] [Schutte et al. 2013]. It mainly focuses on Data-Interchange (or more specifically, Data-Artefact-Mapping) on a semantic level. In this project an ontology has been created (EMERGEL) whose main objective was the mapping of different predefined information artifacts, information representations and languages between countries in Europe. In a RESCUER context, the EMERGEL ontology seems to be quite useful as an up-to-date database, if the task of semantically mapping incident information was the objective. For all other aspects needing to be addressed, the interoperability with legacy systems, for instance, EDXL seemed to be more suitable. However, the use of EMERGEL may be investigated in the future for enabling cross-border incidents in Europe.

In addition to the DISASTER project, several works that use ontologies and EDXL in the context of Emergency and Crisis Management were found. Some of these are presented in this section.

The IC.NET (Incident Command NET) is a system that can be used for Emergency Services such as incident representation, triage, and more. It is based on EDXL-DE as a top level loose coupler used for delivery and exposure of operational level Emergency Services / First Responder data [McGarry and Chen 2010].

The TRIDEC[3] project is based on the GITEWS (German Indonesian Tsunami Early Warning System) and the DEWS (Distant Early Warning System). It provides a service platform for both sensor integration and warning dissemination. Warning messages are compiled and transmitted in the OASIS Common Alerting Protocol (EDXL-CAP) together with addressing information defined via the OASIS Emergency Data Exchange Language - Distribution Element (EDXL-DE) [Hammitzsch et al. 2012].

WebPuff is a system sponsored by the U.S. Army CMA(Chemical Material Activity)and developed by IEM, a security consulting firm based in North Carolina's Research Triangle Park. WebPuff provides users at CSEPP (Chemical Stockpile Emergency Preparedness Program) sites with a suite of planning and response tools that are integrated

[3]Project Collaborative, Complex and Critical Decision-Support in Evolving Crises

with a unique chemical dispersion model that provides an advanced level of science on which decisions about public protection can be based.

In order to ensure interoperability with civilian jurisdictions, the system uses the Emergency Data eXchange Language (EDXL) Common Alerting Protocol (CAP) developed by the Organization for the Advancement of Structured Information Standards (OASIS) [Beriwal and Cochran 2013].

The German Research Centre for Geosciences developed a model for integrating the national tsunami warning system on a large scale. They proposed a system based on existing protocols such as EDXL Common Alert Protocol (EDXL-CAP) and the Distribution Element (EDXL-DE) [Lendholt et al. 2012].

3. EDXL-RESCUER Ontology

EDXL is a set of packages of XML-based messaging standards that favor emergency information sharing between organizations and systems. EDXL standardizes messaging formats for communications between these parties. It was developed by OASIS (Organization for the Advancement of Structured Information Standards) [OASIS 2014]

EDXL is a broad enterprise to generate an integrated framework for a wide range of emergency data exchange standards. The EDXL has several packages: EDXL-DE (Distribution Element); EDXL-RM (Resource Messaging); EDXL-SitRep (Situation Reporting); EDXL-HAVE (Hospital Availability Exchange); EDXL-TEP (Tracking of Emergency Patients); EDXL-CAP (Common Alerting Protocol) and EDXL-RIM (Reference Information Model) [OASIS 2014].

An ontology for the semantic integration of data exchange between the RESCUER platform and legacy systems has been defined based on EDXL standards. The current version of EDXL has seven (7) packages and covers a full range of message contexts in an emergency. The extended scope of EDXL has raised several questions, including: (i) Should an ontology be constructed for all packages? (ii) What message contexts are important for RESCUER? (iii) What kind of information will be exchanged with legacy systems?

In order to clear up these doubts, other RESCUER documents related to Requisites and Architecture tasks were analyzed. They were chosen because they provide useful information that can be used in semantic integration of RESCUER with legacy systems. Based upon this study, a list of competency questions can be designed, which serve as a basis for the selection of EDXL packages for RESCUER domain.

Therefore, in order to address these questions, four packages were chosen: EDXL-DE, EDXL-RM, EDXL-SitRep and EDXL-CAP. Four new ontologies were created, one for each chosen package. These were based on ERM and Data Dictionary of their associated standard. These four ontologies comprise the EDXL-RESCUER ontology and the formalization of the first version of them can be found in our previous paper [Barros et al. 2015].

With this first version of the ontology, a validation through competency questions, where each competency question is related with the correspondent ontology elements can be performed, as seen in (Table 1). In this way, the selection of EDXL packages can be validated. This validation also contributes to a first step of evaluation of the ontology.

Table 1. Competency questions X EDXL-RESCUER ontology

Competency Questions	Ontology element correspondent
Where was the incident?	EDXL-RM owl:Class Location EDXL-CAP owl:Class Area
What kind of incident was it?	EDXL-CAP owl:Class Category EDXL-SITREP owl:Class IncidentCause
Which resource (human or material) will be necessary?	EDXL-RM owl:Class RequestResource or another ResourceMessage subclass
When (date and time) did the incident happen?	EDXL-SITREP owl:DataProperty incidentstartdatetime
What is the weather forecast?	EDXL-SITREP owl:DataProperty weatherEffects
How many people have been affected? (deaths, injuries, evacuations)	EDXL-SITREP owl:Class CasualtyandIllnessSummaryReport and related properties
Who reported the incident?	EDXL-DE owl:Class Sender
What kind of message content was sent by the workforces?	EDXL-DE owl:Class ContentDescription

As an incremental approach is being used, in this paper an update of EDXL-RESCUER ontology based on faceted taxonomy formalization as well as its implementation is presented.

3.1. Update of EDXL-RESCUER Ontology

In order to update the EDXL-RESCUER [Barros et al. 2015], we made an in-depth analysis of the data model for the EDXL scheme. During this process, a natural way was to choose Prieto-Diaz proposal [Prieto-Diaz 1987], a technique used for classifying concepts called Faceted Taxonomy. This approach uses a faceted taxonomy with the purpose of improving and reviewing an existing domain ontology. The facets handle three or more dimensions of classification and can be used when it is possible to organize the entities by mutually exclusive and jointly exhaustive categories.

In line with this approach, in [Denton 2003] a method is presented for making a faceted classification using seven steps. These steps adapted for EDXL-RESCUER ontology update are shown below:

a) Domain collection: we used the EDXL Documentation;
b) Entity listing: we listed all entities found;
c) Facet creation: we arranged all entities that resembled under a main entity, the facet (main entity was chosen to represent a domain segment EDXL);
d) Facet arrangement: we made sure that the entities resembled to the associated facets, reorganizing them when appropriate, (the checks were made through the EDXL documentation, which contains the description and data model for the entities).
e) the citation order and f) classification – phases that refer to how the taxonomy would be implemented. In our case, the goal was the creation of an ontology, then

we defined what every element under a facet and the facet itself would be in an OWL ontology, i.e. what is a class, sub-class, object property, and data property.
g) The last phase included revision, testing, and maintenance: the result of this phase is EDXL-Rescuer v2.

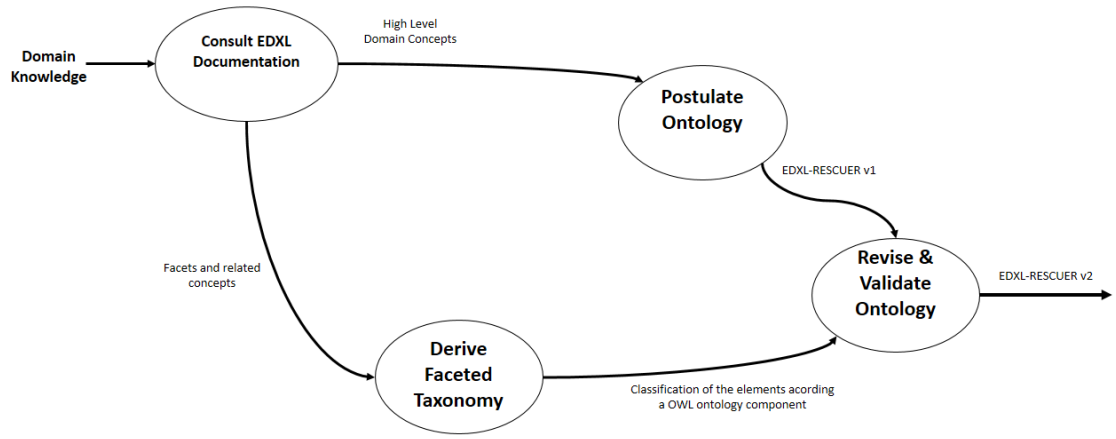

Figure 3. Review and building process of ontologies - Based on [Prieto-Díaz 2003]

Figure 3 summarizes the entire process of the EDXL-RESCUER update. The first version of the ontologies that composed the EDXL-RESCUER relied on EDXL documentation and the ERM models available there. Hence, a faceted taxonomy based on the same documentation, which allowed one to better detail the domain of each chosen pattern was created. Moreover, we were able: (i) to determine the main concepts with higher precision; and (ii) to use the results for reviewing and revalidate the ontologies created at the first iteration.

For instance, the concepts Severity, Urgency and Certainty found in EDXL-CAP. After the procedure previously mentioned (the concepts reviewing), those concepts became classes instead of DataProperties. Those classes received sub-classes with the ability to have different values according to the EDXL documentation as can be seen in Figure 4.

Another improvement from the previous version is that we were able to reuse common concepts among more than one type of EDXL pattern. Hence, Severity, Urgency and Certainty, which EDXL-SitRep also employs, they are imported concepts from EDXL-CAP; therefore the URI is the same as found on the original ontology.

The approach based on faceted taxonomy seemed to be adequate, considering that this technique for classifying concepts is characterized by randomly choosing the terms that represent concepts within a domain (facets). Furthermore, it chooses the relationship between other domain terms and the terms previously chosen, creating categories (each of which is related with a facet). Finally, the faceted approach selects the terms and the relationship between them within the same category or between categories [Dahlberg 1978]

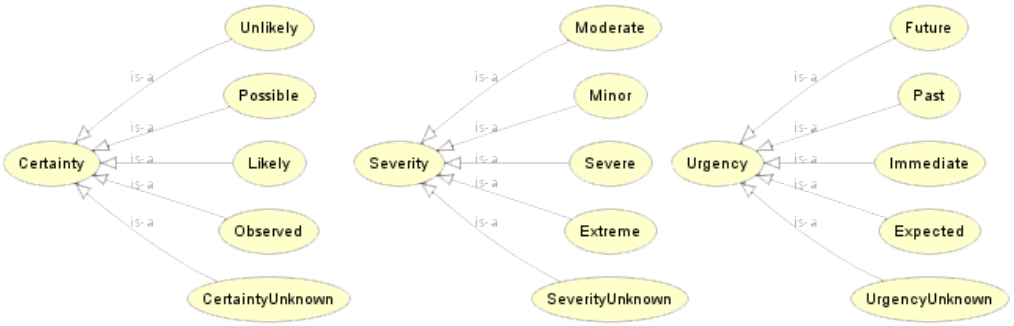

Figure 4. Concepts Urgency, Severity and Certainty - Partial Taxonomy of EDXL-CAP

[Prieto-Díaz 1990]. Additionally, a faceted approach relies not on the breakdown of a universe of knowledge, but on building up or synthesizing from the subject statements of particular documents and that facet can be constructed as perspectives, viewpoints, or dimensions of a particular domain [Prieto-Díaz 2003].

Table 2. Relationship definitions (EDXL-CAP)

Concept1	Relationship	Concept2	Restriction
AlertMessage	hasIncidentRelated	Incident	some
AlertMessage	hasInfo	Info	Min 0
AlertMessage	hasMsgType	MsgType	Max 1
AlertMessage	hasScope	Scope	Max 1
AlertMessage	hasStatus	Status	Max 1
AlertMessage	hasSender	Sender	Max 1
Info	hasArea	Area	some
Info	hasCategory	Category	Max 1
Info	hasResource	Resource	some
Info	hasResponseType	ResponseType	Max 1
Info	hasCertainty	Certainty	Max 1
Info	hasSeverity	Severity	Max 1
Info	hasUrgency	Urgency	Max 1

3.2. Implementation

Due to space limitation, only part of the EDXL-RESCUER ontology is shown. The concepts that make up the EDXL-CAP Ontology and their definitions are:

- AlertMessage: Refers to all component parts of the alert message.
- Info: Refers to all component parts of the info sub-element of the alert message.
- Resource: Necessary element to deal with an emergency. A Resource contains information about its Identity, Description and Status.
- Incident: Term referring to occurrences of any scale that may require some form of Emergency Response and Management, and that requires tracking and information exchange.
- ResponseType: Refers to the type of action recommended for the target audience.

- Area: Refers to all component parts of the area sub element of the info sub element of the alert message.
- Category: Refers to the category of the subject event of the alert message
- MsgType: Refers to the nature of the alert message.
- Status: Refers to the appropriate handling of the alert message.
- Scope: Refers to the intended distribution of the alert message.
- Sender: The originator of an alert.
- Certainty: The certainty of the subject event of the alert message
- Severity: The severity of the subject incident or event.
- Urgency: The urgency of the subject event of the alert message

Table 2 presents the definition of their relationships. The following semantics are used:

Zero or more objects of `<Concept1>` `<Relationship>` with `<Restriction>` objects of `<Concept2>`.

Where `<Restriction>` can be `some, all, Max 1, Min 0, Exactly 1`. `Min 0` is the default value.

Some axioms have also been defined, for instance: (i) Private, Public and Restricted - subclasses of Scope – are disjoint concepts; (ii) Actual, Draft, Exercise, System and Test – subclasses of Status - are disjoint concepts too.

4. Evaluation

The evaluation occurred during the RESCUER Brazilian Consortium Meeting on July 21-23, 2014 and had the goal of validating the terms with potential RESCUER users in Brazilian side. Next, the Goals, Method and Results of this evaluation will be presented.

4.1. Goals

- To present some ontology terms to the stakeholders - terms which were chosen because they represent the main classes of the selected EDXL packages and were the most controversial for both industrial parks (InPa) and large-scale events (LSE);
- To match those terms with the vocabulary the stakeholders use on a daily basis in order to extract synonyms and verify differences, if differences exist, between InPa and LSE.

4.2. Method

The “brainstorm technique” was used in order to capture stakeholder feedback concerning the ontology terms.

The stakeholders were divided into two groups;

- Industrial parks (COFIC)
- Large-scale events (CICC)

During this session, the EDXL concepts were shown to the experts and they tried to find synonyms or correlated terms used in their contexts. At the end of the session, there was an open discussion about the findings related to main concepts of EDXL-RESCUER ontology.

4.3. Results

Based on the activity conducted with the stakeholders, it can be deduced:

- The concepts related to EDXL-SitRep package, in the COFIC context, were suitable;
- Some concepts, for instance the term "incident", had minor variations between the two groups;
- Almost all EDXL terms had related instances or synonyms according to this activity.
- The exception was the term "Jurisdiction", which did not have an instance or a synonym for COFIC. However, at CICC, was found a related instance.
- Some collected terms can be used as instances for populating the EDXL-RESCUER ontology in the future.

This activity raised some important conclusions:

- The necessity of validating all concepts with Brazilian stakeholders;
- A deep investigation of the differences between industrial parks and large-scale events in Brazil; and
- The need to replicate this activity in the European scenario

It is important to note that the differences between the scenarios (COFIC and CICC) emphasize the need for an Interlingua and the relevance of this proposal - EDXL-RESCUER as a common basis for communication.

5. Conclusion

This paper discuss the conceptual model for semantic integration – EDXL-RESCUER ontology. It aims to integrate, semantically, the RESCUER system with legacy systems. In particular, this paper presents an updated version of the ontologies that composed EDXL-RESCUER based on a faceted taxonomy approach. This approach relied on a bottom-up analysis of the EDXL documentation in order to synthesizing the subject statements of these documents. It is important to note that the construction of facets provides different perspectives and views of the domain. In this way, we were able to review our first version of EDXL-RESCUER ontology and adjust its concepts and relationships.

Moreover, in regards to the evaluation, the legacy systems information and data are still missing, as well as the data from RESCUER base. After populating the EDXL-RESCUER ontology, we are going to validate it using reasoning algorithms and queries. Another step is to implement the ontology-based integration module between RESCUER and legacy systems.

Some further investigations will be carried out as well: (i) the use of LOD (Linked Open Data) in this context; (ii) the use of the EMERGEL-knowledge base as an additional controlled vocabulary or just as a synonym-base.

6. Acknowledgements

This research is part of the RESCUER (Reliable and Smart Crowdsourcing Solution for Emergency and Crisis Management) project funded by European Union under grant reference 614154 and by CNPq under grant reference 490084/2013-3. This work also was partially supported by the National Institute of Science and Technology for Software Engineering (INES), funded by CNPq, grant 573964/2008-4.

References

Azcona, E. R. (2013). Disaster data interoperability solution at stakeholders emergency reaction. http://disaster-fp7.eu/sites/default/files/D3.22.pdf.

Barros, R., Kislansky, P., Salvador, L., Almeida, R., Breyer, M., and Gasparin, L. (2015). Edxl-rescuer ontology: Conceptual model for semantic integration. In *Proceedings of the 12th International ISCRAM Conference*.

Beriwal, M. and Cochran, B. (2013). Protecting communities from chemical warfare agents. In *Technologies for Homeland Security (HST), 2013 IEEE International Conference on*, pages 418–422. IEEE.

Besaleva, L., Weaver, A. C., et al. (2013). Applications of social networks and crowdsourcing for disaster management improvement. In *Social Computing (SocialCom), 2013 International Conference on*, pages 213–219. IEEE.

COFIC (2009). Cofic polo - comitê de fomento industrial de camaçari. https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emergency.

Dahlberg, I. (1978). Teoria do conceito. *Ciência da informação*, 7(2).

Denton, W. (2003). How to make a faceted classification and put it on the web. https://www.miskatonic.org/library/facet-web-howto.html.

Eccher, C., Scipioni, A., Miller, A. A., Ferro, A., and Pisanelli, D. M. (2013). An ontology of cancer therapies supporting interoperability and data consistency in eprs. *Computers in biology and medicine*, 43(7):822–832.

Fernández-López, M., Gómez-Pérez, A., and Juristo, N. (1997). Methontology: from ontological art towards ontological engineering.

Genc, Z., Heidari, F., Oey, M. A., van Splunter, S., and Brazier, F. M. (2013). Agent-based information infrastructure for disaster management. In *Intelligent Systems for Crisis Management*, pages 349–355. Springer.

Grüninger, M. and Fox, M. S. (1995). Methodology for the design and evaluation of ontologies.

Hammitzsch, M., Reißland, S., and Lendholt, M. (2012). A walk through tridec's intermediate tsunami early warning system. In *EGU General Assembly Conference Abstracts*, volume 14, page 12250.

Kilgore, R., Godwin, A., Hogan, C., et al. (2013). A precision information environment (pie) for emergency responders: Providing collaborative manipulation, role-tailored visualization, and integrated access to heterogeneous data. In *Technologies for Homeland Security (HST), 2013 IEEE International Conference on*, pages 766–771. IEEE.

Lendholt, M., Esbri, M., and Hammitzsch, M. (2012). Interlinking national tsunami early warning systems towards ocean-wide system-of-systems networks. In *Proceedings of the 9th international ISCRAM conference, Vancouver, Canada*.

McGarry, D. P. and Chen, C. R. (2010). Ic. net—incident command "net": A system using edxl-de for intelligent message routing. In *Technologies for Homeland Security (HST), 2010 IEEE International Conference on*, pages 197–203. IEEE.

Mescherin, S., Kirillov, I., Klimenko, S., et al. (2013). Ontology of emergency shared situation awareness and crisis interoperability. In *Cyberworlds (CW), 2013 International Conference on*, pages 159–162. IEEE.

OASIS (2014). Oasis emergency management tc. `https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emergency`.

Prieto-Diaz, R. (1987). Domain analysis for reusability. In *Proceedings of COMPSAC*, volume 87, pages 23–29.

Prieto-Díaz, R. (1990). Domain analysis: An introduction. *ACM SIGSOFT Software Engineering Notes*, 15(2):47–54.

Prieto-Díaz, R. (2003). A faceted approach to building ontologies. In *Information Reuse and Integration, 2003. IRI 2003. IEEE International Conference on*, pages 458–465. IEEE.

Schutte, F., Rubén, C., and Emilio, R. (2013). Solving interoperability issues in cross border. In *Proceedings of the 10th International ISCRAM Conference*, pages 238–241.

Shah, T., Rabhi, F., and Ray, P. K. (2013). Oshco: A cross-domain ontology for semantic interoperability across medical and oral health domains. In *e-Health Networking, Applications & Services (Healthcom), 2013 IEEE 15th International Conference on*, pages 460–464. IEEE.

Shan, G., Rui, G., Wenjun, W., and Xiankun, Z. (2012). Research on ontology-based emergency situation data integration and sharing. *Journal of Convergence Information Technology*, 7(9).

Villela, K., Vieira, V., Mendonça, M., Torres, J., and Graffy, S. (2013). Rescuer-dow - reliable and smart crowdsourcing solution for emergency and crisis management.

Xiao, H., Qiu, T., and Zhou, P. (2013). Integration of heterogeneous agriculture information system based on interoperation of domain ontology. In *Agro-Geoinformatics (Agro-Geoinformatics), 2013 Second International Conference on*, pages 476–480. IEEE.