EDXL-RESCUER ontology: Conceptual Model for Semantic Integration

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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, it 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.

Keywords Emergency, Crisis, RESCUER, EDXL, Ontology

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 solution for different problems (Beriwal, et al., 2013; Besaleva, et al., 2013; Eccher, 2013). This paper is part of a research for developing a crowdsourcing solution for emergency management, the RESCUER project (Villela, et al. 2013).

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

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:

- Mobile Crowdsourcing Solution: support eyewitnesses' communication with official first responders (police, fire fighter, 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 flowing between the stakeholders; and
- Emergency Response Toolkit: is 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 Brazilian partner is the COFIC (COFIC 2009) (Industrial Development Committee of Camaçari), it manages security simulations and deals with legal procedures and media. The Brazilian Security Forces represented by the CICC (Integrated Command and Control Centre) while in Europe is the FIRESERV[2] that have contributed the project with expertise knowledge on how command and control centers operate in large-scale events as well as in industrial areas.

Interoperability between the RESCUER project and legacy systems is critical for the success of the solution. For the purpose of semantic and seamless integration of legacy systems, the use of ontologies seems to be most suitable. This is because they offer a basis for a shared and well-formed specification of a particular domain. Hence, in this proposal, we are going to present an ontology that will comprise the RESCUER conceptual model related to the coordinating and exchanging of information with legacy systems.

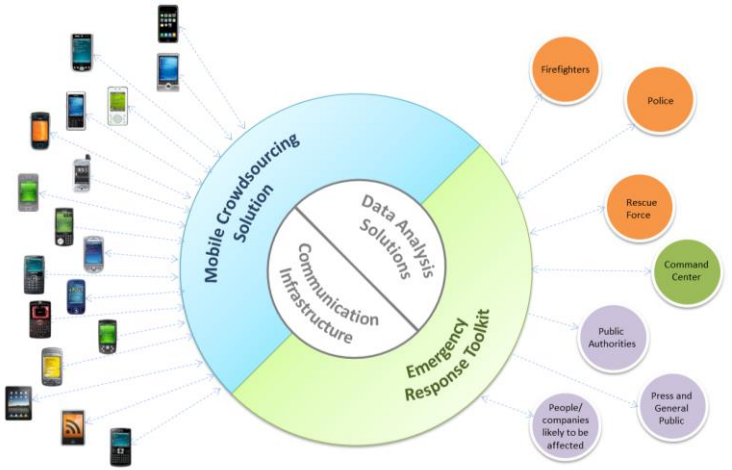

Figure 1 - Conceptual model of RESCUER

From this perspective, the use of a well-referenced standard by the scientific community-- the EDXL (OASIS, Oasis emergency management tc. 2014) – Emergency Data eXchange Language--, as a basis for the new ontology was chosen. EDXL is a common standard, 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.

The evaluation was performed in two steps:

1. Validation through competency questions - questions that an ontology should

[2] http://www.fireserv.at/ . Accessed on May 10, 2014.

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) (Gruninger e Fox 1995) and the METHONTOLOGY (Fernandez-Lopez, Gomez-Pérez e Juristo 1997).

2. Brainstorm with potential end users for validating the ontology terms. The results show that the EDXL-RESCUER ontology is suitable for the specific goal proposed in this paper.

This paper is structured as follows. In the Related work section, we present research projects related to emergency, ontology and interoperability. We then describe an overview of the EDXL standard. Next, we present the methodology used for building the EDXL-RESCUER ontology. In the Evaluation and Results sections we present a initial evaluation and the results derived from that; Finally, conclusion of the work done and future developments.

RELATED WORKS

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

Among the reviewed literature, one project stood out - the DISASTER (Data Interoperability Solution at Stakeholders Emergency Reaction) (Azcona 2013; Schutte, Casado and Rubiera 2013) project. 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 for different predefined information artefacts, 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, we may investigate the use of EMERGEL in the future for enabling cross-border incidents in Europe.

Besides the DISASTER project, we found several works that use ontologies and EDXL in the context of Emergency and Crisis Management. Some of them are presented in this section.

The IC.NET (Incident Command NET) is a system that can be use 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) providing a service platform for both sensor integration and warning dissemination. Warning messages are compiled and transmitted in the OASIS Common Alerting Protocol (CAP) together with addressing information defined via the OASIS Emergency Data Exchange Language - Distribution Element (EDXL-DE) (Hammitzsch, Reibland and Lendholt 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 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).

EDXL

EDXL is a set of packages of XML-based messaging standards that favor emergency information sharing between organizations and systems. EDXL

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

standardizes messaging formats for communications between these parties. It was developed by OASIS (Organization for the Advancement of Structured Information Standards) (OASIS n.d.).

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 n.d.).

EDXL-RESCUER ONTOLOGY

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 standard version has seven (7) packages and covers a full range of message contexts in an emergency. This provokes several things to be reflected upon. To wit, (i) Should an ontology be constructed for all packages? (ii) What message contexts are important for RESCUER? (ii) What kind of information will be exchanged with legacy systems?

In order to clear up these doubts, we analyze others RESCUER documents related to Requisites and Architecture tasks, and 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 (Table 1) can be designed, which serve as a basis for the selection of EDXL packages for RESCUER domain.

Competency Questions

1. Where was the incident?
2. What kind of incident was it?
3. Which resource (human or material) will be necessary?
4. When (date and time) did the incident happen?
5. What is the weather forecast?
6. How many people have been affected? (deaths, injuries, evacuations)
7. Who reported the incident?
8. What kind of message content was sent by the workforces?

Table 1 - EDXL-RESCUER Competency questions

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.

Formalization

Some criteria were used to translate the EDXL elements to an OWL (Web Ontology Language) file, i.e., to formalize ERM in OWL. These criteria are based on literature (Horridge 2011; ODM - Ontology Definition Metamodel 2009) about mapping UML into OWL – ERM is based on UML – and based on the description semantics of EDXL Data Dictionary. Table 2 summarizes the transformation process and Figure 2 shows the translation details.

ERM element	Description	OWL element	Example (in figure 2)
Class	Concept, which describes a set of elements with common characteristics.	Class owl:class	elements X and Y
Simple attribute	Attributes that receive a literal value with only one fill option.	Data Properties owl:DataProperty	elements w3 and w4

Composite attribute	Attributes that receive different values, which can influence the existence of other attributes.	Class owl:class	elements W1 and W2
Inheritance	Relationship between a specific class and a general class.	Taxonomy rdfs:subClassOf	Element X (general class) and elements T, U and V (specific class)
Association	Binary relation between two classes.	Object Properties owl:ObjectProperty	**hasY** (domain: X and range:Y)

Table 2 - ERM to OWL

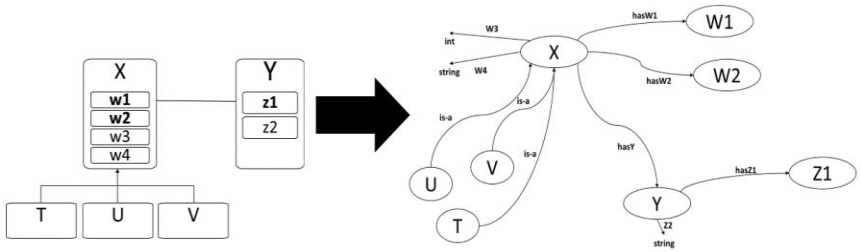

Figure 2 - Transformation process

Implementation

Due to space limitation, we show only part of the EDXL-RESCUER ontology, as an example of part of our work, Figure 3 provides a graphical representation of some of the concepts and the relationships that make up the EDXL-CAP Ontology.

Those concepts definitions are:

- **Alert**: 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.

Concept1	**Relationship**	**Concept2**	**Restriction**
Info	hasArea	Area	some
Info	hasCategory	Category	Max 1
Alert	hasIncidentRelated	Incident	some
Alert	hasInfo	Info	Min 0
Alert	hasMsgType	MsgType	Max 1

Info	hasResource	Resource	some
Info	hasResponseType	ResponseType	Max 1
Alert	hasScope	Scope	Max 1
Alert	hasStatus	Status	Max 1

Table 3 - Relationship definitions (EDXL-CAP)

Table 3 presents the definition of the respective relationships. We have the following semantics: 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.

We also defined some axioms. For instance, **Private**, **Public** and **Restricted** - subclasses of **Scope** – are ***disjoint*** concepts.

Actual, Draft, Exercise, System and Test – subclasses of **Status** - are ***disjoint*** concepts too.

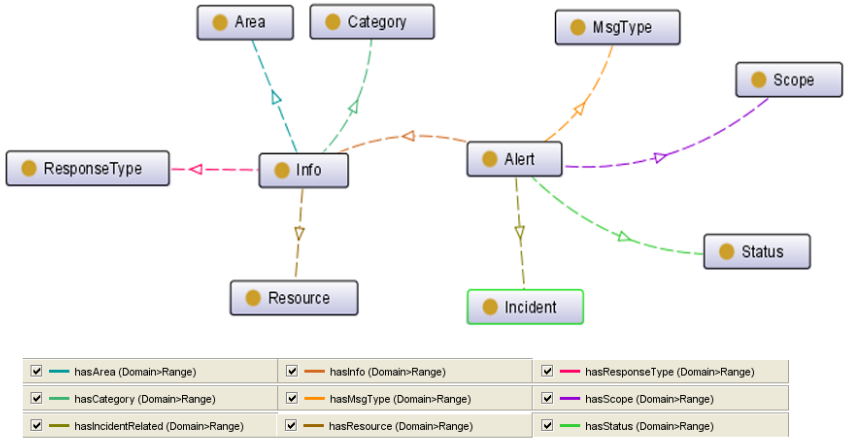

Figure 3 - Graphical Representation of Relationships (EDXL-CAP)

EVALUATION

The evaluation was conducted in two steps: first, we related each competency question with the correspondent ontology elements (table 4); second, the evaluation occurred during the RESCUER Brazilian Consortium Meeting on July 21-23, 2014 and has the goal of validating the terms with potential RESCUER users in Brazilian side.

Competency Questions	**Ontology element correspondent**
Where was the incident?	EDXL-RM owl:Class **Location** EDXL-CAP owl:Class **Area**
What kind of incident?	EDXL-CAP owl:Class **Category** EDXL-SITREP owl:Class **IncidentCause**
Which kind of 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 *incident_startdatetime*
What is the weather forecast?	EDXL-SITREP owl:DataProperty *weatherEffects*
How many people are 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**

Table 4 - Competency questions X EDXL-RESCUER ontology

Goals (Second Evaluation)

i. 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);

ii. 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.

Method (Second Evaluation)

The "brainstorm technique" was used in order to capture stakeholder feedback concerning the ontology terms. Figure 4 describes the steps of this brainstorm.

- The stakeholders were divided into two groups;
  - Industrial parks (COFIC)
  - Large-scale events (CICC)

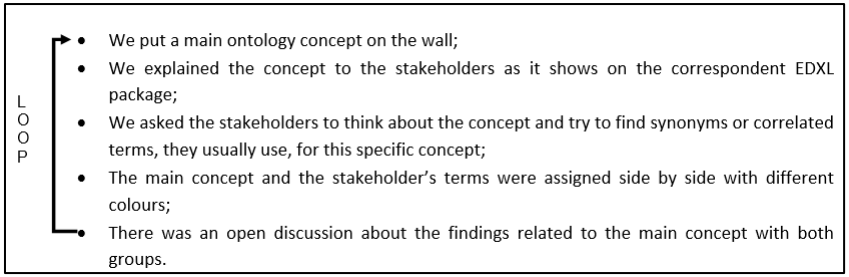

Figure 4 - Brainstorm process

RESULTS

Based on the activity we conducted with the stakeholders, we can deduce:

- 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.

- We can use some collected terms 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;
- Investigate deeply 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.

CONCLUSION

This paper presents the construction process of the conceptual model for semantic integration – EDXL-RESCUER ontology. It aims to integrate, semantically, the RESCUER system and legacy systems. The expectation is that the legacy systems have used, or will use, the EDXL standard in their interface and data model. A set of competency questions based on RESCUER requisites and architecture guided the selection of EDXL packages: DE, RM, SitRep and CAP. With the initial evaluations, we could realize: (i) how the new ontologies would respond to the competency questions; (ii) that EDXL was a good choice: the partners of the two groups (Industrial parks /Large-scale events) use terms that are synonymous/instances of EDXL main terms.; (iii) EDXL-RESCUER provides a common basis of communication between two partners in Brazil.

Continuing, 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.

Therefore, in the following steps, it will be necessary to: (i) Obtain data from the RESCUER base; (ii) Obtain data from legacy systems; (iii) Populate the ontologies and validate them; (iv) Map the ontology concepts to (at least) one legacy system domain; (v) Implement the interoperability schema (based on ontology) between RESCUER and (at least) one legacy system.

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.

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