Design and modeling of a domain ontology for fire protection

Jens Pottebaum
Universität Paderborn, C.I.K.
pottebaum@cik.upb.de

Anna Maria Japs
Universität Paderborn, C.I.K.
japs@cik.upb.de

Stephan Prödel
Universität Paderborn, C.I.K.
s.proedel@cik.upb.de

Rainer Koch
Universität Paderborn, C.I.K.
r.koch@cik.upb.de

ABSTRACT

The semantics of things represent the central problem of the heterogeneous domain of emergency response. Both the communication between human actors and the interface between information systems face this hurdle with high impact on the efficiency in mission and time critical command and control processes. The integration of applications and information sharing based on semantic technologies promise added value for a solution to this problem. Therefore a model of the domain is essential; this paper contributes a domain ontology for fire protection. The scientific discussion as well as expert interviews built the basis for a new modeling approach. The selection of ontology languages is one of the important design issues presented in this paper.

Keywords

Domain ontology, fire protection, interoperability, information sharing, semantic technologies

INTRODUCTION OF CASE STUDY

Private and professional information are formed every day – they are the basis for actions and decisions (Müller 2001). On one side quick and definitive decisions are needed in critical situations, on the other side extensive information to prevent incorrect decisions are needed (Strohschneider 2007).

Fire brigades encounter this situation during their operations. The officer-in-charge has to evaluate the current situation after the arrival. Therefore he will try to gather as much information as possible in a short period of time. Fire brigade plans contain some of these data for first information. Additional data like architectural drawings, hazmat databases or detailed maps exist at different places, but it is impossible to collect all the relevant information to every possible incident in advance because of the resulting amount of data. Furthermore an a priori arrangement would bring the disadvantages of redundant records, as for example missing actuality and the danger of inconsistencies. In contrast the realization of an "on demand" service is not a problem due to the availability of modern mobile communication infrastructure (Rohrer 2009).

The challenge is to extract the relevant information from the huge number of available data. An automation of this process would be especially helpful with the time critical operations of fire brigades because they do not allow time intense research. An approach to computer assisted classification by semantic modeling of the available resources with ontologies is currently being examined in the German research project[1] Mobis Pro. Within the generic approach the design of a domain ontology for fire protection is a major challenge. This paper highlights the main requirements and design decisions as well as specialties of this domain. This work-in-progress is discussed within its application context and various approaches in current research.

Reviewing Statement: This paper represents work in progress, an issue for discussion, a case study, best practice or other matters of interest and has been reviewed for clarity, relevance and significance.

[1] For more information cp. URL http://www.mobispro.de

ONTOLOGIES FOR EMERGENCY RESPONSE

Obviously the most important foundation for this work is the definition of an ontology. Based on (Gruber 1993) the definition of (Studer et al. 2001, translated from German) highlights the common modeling and utilization of an ontology: "An ontology is a formalized, explicit specification of a common conceptualization." Two major types of existing approaches are distinguished in this paper: Specific ontologies for crisis management and generic ontologies applied in this domain. Many papers address the challenges which are defined by a heterogeneous group of stakeholders and the semantics of their application domain (cp. Xu and Zlatanova 2007). Most of them request the development of a common intermediate vocabulary:

- Promising approaches are driven by the domain of geo informatics resp. the application of GIS for crisis management. The approach of (Andrienko and Andrienko 2007) consists of five categories: Events, dangers, public groups, tasks and resources/infrastructure. Besides this the separation of data and location based concepts is discussed as a central requirement (cp. Klien and Probst 2005).
- The Emergency Information Interoperability Framework XG resp. its members collected and analyzed existing standards like CAP, EDXL and NIMS[2]. One major finding is that ontologies are required as an agreement on a common vocabulary and common semantics is not possible (cp. Iannella 2005). Additionally (Di Maio 2007) emphasizes that an open implementation is necessary to reach a high level of interoperability in this domain (cp. also the SAHANA project). These approaches were done for large scale catastrophes. The applicability for daily use resp. regional incidents has to be researched on.
- Babitski et al. use an upper level ontology (Babitski et al. 2009, cp. also Masolo et al. 2002) and describe the modeling approach for a domain ontology. The separation of "Model of tactical unit descriptions (as per regulations) and tactical units (as maintained in practice)" within the resource ontology represents an important aspect which needs to be scrutinized.
- The project CoSAR-TS builds up on a broad approach incorporating the <I-N-C-A> ontology (Tate 2003). This ontology is part of an ontology set and is used by the I-X framework resp. the KaOS system (cp. Wickler et al. 2006). The latter also utilizes the KaOS Policy Ontology which contains concepts for the general environment of an actor and rules within this context. The KaOS system loads additional ontologies to extend generic concepts by use case related ones (Tate et al. 2006).
- For the SHARE (EU funded research project) ontology rules, directives and guidelines of the domain were modeled by description logics; by applying consistency checks these descriptions were transferred to decision support information (Pottebaum et al. 2007).

DOMAIN ONTOLOGY FOR FIRE PROTECTION

The origin of the modeling approach is built by the fire brigade as a class of organizations which is represented by its major regulations and directives. It is extended by additional documents and practical information and experiences carrying rule definitions. Besides the fire brigade other organizations have to be taken into account; in Germany especially the emergency medical service, rescue services and technical relief organizations.

Requirements specification

The *Domain Ontology* must be conformant to the definition of Studer et al. and create a common sense of the specific domain between humans and computers. Uschold and Gruninger (1996) discuss the assignment of *Domain Ontologies* which either are used in the original domain or are integrated in another domain. Based on these reflecting applicability as well as decidability and modularity (normalization) can be deducted as specific requirements (cp. Rector 2003 for a concrete set of modelling requirements). Klien and Probst (2005) constitute important requirements for the scope of geographic information system. Especially the separation of things in the real world and their data representation is a core requirement for the representation of real events (*the dangers*, cf. Babitski et al. 2009). These principal technical requirements are complemented by validated domain expert input. The requirement to model funded and resilient domain knowledge will be detailed in the following paragraphs. The information deposited in this knowledge must be represented in the ontology adequately:

- Modeling of concepts and logical constraints which are specified in domain specific documents
- Separation between basically valid names and process-related concepts (core process: *the operation)*

[2] For a full list of results see URL http://www.w3.org/2005/Incubator/eiif/wiki/EMInfoStdsReview

- Representation of real processes and structures incl. the defined set of rules and "pragmatic" attempts
- Representation of all phases of fire protection (cp. Khalil et al. 2008 for a list of categories).
- Combination of *data ontologies* and *organizational ontologies* as stated by (Xu and Zlatanova 2007)

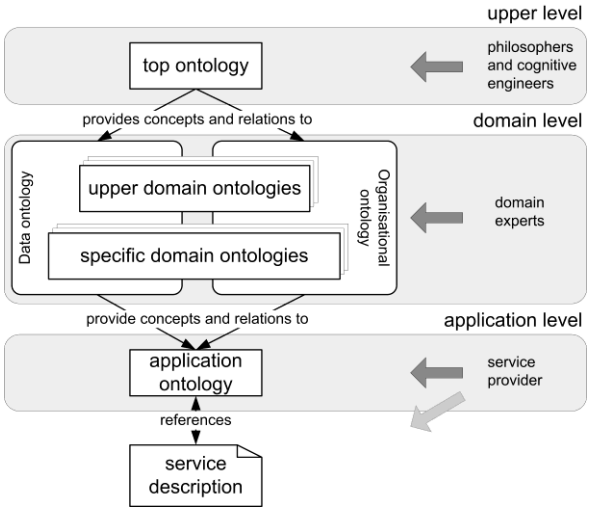

Figure 1. Three level architecture for the domain ontology following the approach of Babitski et al. 2009, adapted to Missikoff et al. 2002 and Xu and Zlatanova 2007

This specification aims at defining an *upper level domain ontology* in terms of figure 1 as well as in support of the definition of *a controlled vocabulary and relations built upon it* (Xu and Zlatanova 2007). A decision for the use of a certain *Top Ontology* is made differently in related work and stays open here at first consciously.

The Choice of F-Logic as an ontology language

Basically F-Logic is an enlargement of predicate logics. It was developed primarily for the natural representation of object-oriented concepts like classes and inheritance (Stuckenschmidt 2009). The potential of F-Logic as an ontology language becomes visible in complex domains like fire protection. In contrast to other ontology languages like RDF, DAML+OIL or OWL it offers the possibility to describe classes, relations, rules and derivation rule in the form of logic programs. The specification of derivation rules allows to express and to model complicated terms with easy means. In fact F-Logic offers a practically oriented and relatively efficient method to formalize domain ontologies. The representation of classes and objects as logical constants enables on the one side the advantageous meta-modeling in practice and on the other side solutions in terms of decidability.

Domain ontology development

For the use case driven research a *bottom-up* approach was selected to start with specific requirements of affected practitioners and to reach a valid level of generalization and portability. Another important aspect is the analysis and explicit separation of the system and its environment. Thereby the frame for the intended domain ontology is set which embodies requirements and criteria for ontology development design decisions.

The starting activity of the research was defined by concepts of the structure of operational and command forces of fire brigades within an operation. This was iteratively extended on a general resource view. Driven by requirements the domain ontology should be divided into single sub-ontologies: The *resources* form the basis of the organization as a bearer of the problems and, concerning operational resources, aid for the conduction of tasks. For a stringent separation of semantically disjoint areas the following categories are distinguished: (a) the structure of the organizations without relation to an acute operation (*cold situation*), (b) the structure within an operation and (c) a defined set of categories. The latter mainly represent standards which categorize resources (e.g., vehicle and qualification standards). Objects must be integrated and accompanying qualities that are relevant for fire prevention must be modeled. This sub-ontology encases the domain areas *population groups* and *infrastructure* according to (Andrienko and Andrienko 2007). *Dangers* originate with reference to objects in the reality and receive a value by this context reference. Hence, they form the basis for the integration of all concepts in the *processes of fire protection*. For fire protection matters this sub-ontology combines,

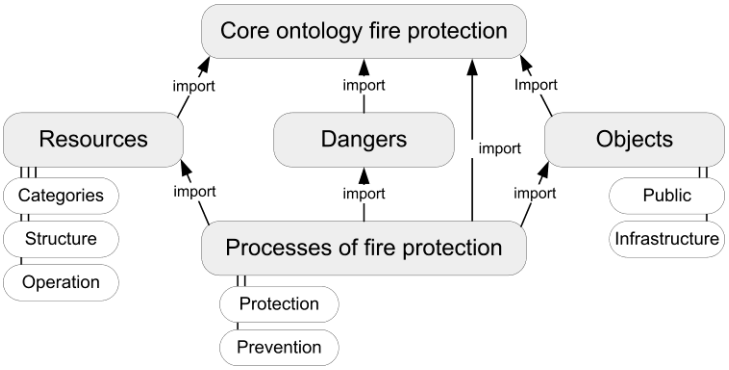

Figure 2. Sub-Ontology of domain ontology

simplistically expressed, (a) the real conduction of tasks by resources and (b) the technical determination of the relations between involved concepts and instances.

DISCUSSION OF DESIGN ASPECTS

The first validation steps with domain experts demonstrate the potential of the approach described in this paper. It is also supported by similar efforts in the specific domain of interest, e. g., Babitski et al. Both research groups base their work on the same approach of separating the incident resp. dangers and the operation resp. civil protection. The approach described in this paper tries to extend this to the specific characteristics of the organizational domain ontology and approaches another decomposition step. Another differentiation is visible concerning the application in non-operational use cases (e. g., training sessions) where high potential can be envisioned.

Still an open point is the identification of a top level ontology: An adequate ontology has to fulfill the specified requirements gathered by the bottom-up approach. Without this definition it is important to mention that the domain ontology has to be valid as a common vocabulary in the problem domain. Based on this assumption it can represent the highest level within an ontology hierarchy in a specialized system. Nevertheless it is planned to analyze the potential for an improved clarity of the vocabulary and the transferability to nearby use cases.

The requirement for clarity and modularity seems to be very helpful for modeling, maintenance and application of the ontology to be used in different business processes (fire prevention and protection). On the one hand separate mechanisms for information management are implemented. On the other hand it is necessary to exchange data and information to increase effectiveness and efficiency in specific processes. Additionally it seems to be reasonable to follow the requirement of separating data from organizational entities. This separation forces a clear modeling approach and especially defined interfaces between sub-models. Within the modeling phase these interfaces have to be explicitly discussed; thereby the problem awareness is sharpened.

The domain of fire protection in Germany is characterized by its heterogeneous actors and a variety of opinions. Thus all aspects besides commonly agreed directives mean great challenges. The same occurs for individual differences in the assessment of situational information based on different experiences. The difficulties which are implied by these effects are visible in defining an expressive logical framework resp. the identification of the reasonable depth of the modeling approach. They are empowered by interorganizational collaboration (technical relief organizations, rescue services, military) and corresponding differences in terminology and used symbols.

OUTLOOK

The ontology is currently developed and validated in cooperation with the city of Dortmund (large professional fire brigade) and the region of Paderborn (high number of volunteer participation). The specific domain ontology is extended based on specific scenarios in fire protection and prevention business processes. For the systematic extension and standardization of an upper domain ontology it is important to include feedback of other experts. Therefore it is planned to integrate it in other ongoing research projects. A comprehensive optimization needs further discussion in the community and between research projects in the German and international domain. Especially the existing standardization efforts like EDXL with its resource management extension EDXL-RM has to be included conceptually further on. Additionally it is important to check cross-links and interdependencies with other approaches in terms of the Semantic Web (cp. the “Open Linked Data

Cloud" of the "Linking Open Data community project"[3]).

REFERENCES

1. Andrienko, N.; Andrienko G. (2007) Intelligent Visulation and Information Presentation for Civil Crisis Management. *Transaction in GIS,* 11(6):889-909.
2. Babitski, G.; Probst, F.; Hoffmann, J.; Oberle, D. (2009) Ontology Design for Information Integration in Disaster Management. In *Informatik 2009. 4th International Workshop on Applications of Semantic Technologies (AST'09)*
3. Di Maio, P. (2007) An Open Ontology For Open Source Emergency Response System. Open Source Research Community, http://opensource.mit.edu/papers/TOWARDS_AN_OPEN_ONTOLOGY_FOR_ER.pdf last visit 30.11.2009
4. Gruber, T. R. (1993) A Translation Approach to Portable Ontology Specification. In: Knowledge Acquisition vol. 6, Nr. 2, Page. 199-221.
5. Iannella, R. (2005) Incident Notification: Requirements and Frameworks, recent advances in conuter-terrorism technology and infrastructure protection: Proceeding of the 2005 Science, Engineering and Technology Summit, Canberra, 12-14 July 2005.
6. Khalil, K. M.; Abdel-Aziz, M.; Nazmy, T. T.; Salem, A.-B. M. (2008) The Role of Artificial Intelligence Technologies in Crisis Response. *CoRR,* abs/0806.1280.
7. Klien, E.; Probst, F. (2005) Requirements for Geospatial Ontology Engineering. In (Toppen, F.; Painho, M.) *8th conference on Geographic Information Science (AGILE 2005),* Page 251-260, Estoril, Portugal
8. Masolo, C.; Borgo, S.; Gangemi, A.; Guarino, N.; Oltramari, A.; Schneider, L.; (2002) WonderWeb Deliverable D17. The WonderWeb Library of Foundational Ontologies and the DOLCE ontology. Report, ISTC-CNR.
9. Missikoff, M.; Navigli, R.; Velardi, P.; (2002) The Usable Ontology: An Environment for Building and Assessing a Domain Ontology. In *ISWC '02: Proceedings of the First International Semantic Web Conference on The Semantic Web*, Page 39-53, London, UK, Springer Verlag.
10. Müller, J. (2001) Business Information Management sorgt für Überblick in der Informationsflut. In (Frischmuth, J.) *Strategien und Prozesse für neue Geschäftsmodelle: Praxisleitfaden für E- und mobile Business,* Page 207-216. Springer Berlin.
11. Pottebaum, J.; Konstantopoulos, S.; Koch, R.; Paliouras, G.; (2007) SaR Resource Management Based on Description Logics. In (Löffler, J.; Klann, M.) *Mobile Response*, LNCS 4458, Page 61-70. Springer Verlag
12. Rector, A. L.; (2003) Modularisation of domain ontologies implemented in description logics and related formalisms including OWL. In *K-CAP '03: Proceedings of the 2nd international conference on Knowledge capture*, Page 121-128, New York, NY, USA, ACM.
13. Rohrer, T. (2009) Analyse: UMTS verfügbar an 77% aller Standorte mit Mobilfunkversorgung
14. Strohschneider, S. (2007) Ed. *Entscheiden in kritischen Situationen.* Schriftenreihe der Plattform Menschen in komplexen Arbeitswelten e.V. Verl. Für Polizeiwissenschaft, Frankfurt a. M., 2. Ed.
15. Stuckenschmidt, H.; (2009). *Ontologien – Konzepte, Technologien und Anwendungen*. Berlin/Heidelberg. Springer Verlag.
16. Studer, R.; Erdmann, M.; Mädche, A. D.; Oppermann, H.; Schnurr, H.-P.; Staab, S.; Sure, Y and Tempich, C. (2001) Arbeitsgerechte Bereitstellung von Wissen – Ontologien für das Wissensmanagement: Arbeitsbericht des Instituts AIFB, Universität Karlsruhe. Karlsruhe.
17. Tate, A.; (2003) Coalition Task Support Using I-X and <I-N-C-A>. In (Marik, V.; Müller, J. P.; Pechoucek, M.) *CEEMAS*, LNCS 2691, Page 7-16. Springer Verlag.
18. Tate, A.; Dalton, J.; Bradshaw, J. M.; Uszok, A.; (2006) Coalition Search and Rescue - Task Support: Intelligent Task Achieving Agents on the Semantic Web. AIAI Contract No. F-30602-03-2- 0014 (DARPA Order No. P105/00), IHMC Contract No. F-30602-00-2-0577. Published as Air Force Research Laboratory Technical Report AFRL-IF-RS- TR-2006-91, via DTIC, Accession Number ADA449044, July 2006

[3] Cp. URL http://richard.cyganiak.de/2007/10/lod/

19. Uschold, M.; Gruninger, M.; (1996) Ontologies: Principles, Methods and Applications. *Knowledge Engineering Review*, 11:93-136.
20. Wickler, G.; Tate, A.; Potter, S.; (2006) Using the Constraint Model as a Shared Representation of Intentions for Emergency Response. In *Fifth International Joint Conference on Autonomous Agents and Multiagent Systems.*
21. Xu, W.; Zlatanova, S.; (2007) Ontologies for Disaster Management Response. *Geomatics Solutions for Disaster Management*, Page 185-200.