Adaptive Ontology Use for Crisis Knowledge Representation

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ABSTRACT

While a crisis requires quick response of emergency management factors, ontology is generally represented in a static manner. Therefore, an adaptive ontology for crisis knowledge representation is needed to assist in coordinating relief efforts in different crisis situations. The paper describes a method of ontology modeling that modifies the ontology in real time during a crisis according to the crisis surroundings. An example of ontology use based on a sample Katrina crisis blog is presented.

Keywords

Knowledge representation, ontology, crisis information mapping

INDEX ONTOLOGY

In the quest to identify frameworks, concepts, and models for crisis ontologies the term 'Open Ontology' was addressed in (Di Maio, 2007). 'Open Ontology' refers to a given set of agreed terms, in terms of conceptualization and semantic formalization, that has been developed based on public consultation and that embodies, represents, and synthesizes all available, valid knowledge thought to pertain to a given domain and necessary to fulfill a given functional requirement.

The Sphere handbook (Sphere Project, 2004) is designed for use in disaster response and may also be useful in disaster preparedness and humanitarian advocacy. It is applicable in a range of situations where relief is required, including natural disasters and armed conflict. It is designed for use in both slow- and rapid-onset situations, rural and urban environments, developing and developed countries, anywhere in the world. The emphasis throughout is on meeting the urgent survival needs of people affected by disaster, while asserting their basic human right to life with dignity.

Analysis of the Sphere handbook Index, displayed in Figure 1, indicates that it meets many requirements of Open Ontology. Thus, the current Index can be defined as an **Index Ontology**. Generic top level requirements for an Open Ontology according to (Di Maio, 2007) include:

· Declaring what high level knowledge (upper level ontology) it references. The Index Ontology primary concepts can be identified by the outer level keywords in the index. These keywords serve as a high level framework defining the primary topics of the Crisis Ontology.

· The ontology allows reasoning / inference based on the index. For example, according to Figure 1 the concept *fuel supplies* is a subclass of *cooking* and also a subclass of the concept *impact*, which is a subclass of the concept *environment*. It is also a subclass of the concept *vulnerable groups*. The hierarchical and relational index structure supplies the initial structure of the Index Ontology.

- cooking
  - fuel supplies 158, 159, 234, 235-6
  - environmental impact 123, 159
  - stoves 234, 235
  - utensils
    - access 163, 164
    - initial needs 233, 242
  - water supplies 64
- coordination
  - food aid 109, 113-14
  - health services 255, 261-3, 263-4
  - information exchanges 30, 33-4, 35
  - shelter programmes 209-10
- crude mortality rates (CMR)
  - baseline 260-1
  - calculations 301
  - documentation 32-3, 259, 271
  - maintenance 259, 260
- cultural practices
  - data gathering 38
  - housing 207, 219, 220, 221, 222, 240
  - normality 291, 293
  - initial assessments 92
  - on-site soak pits 87-8
  - planning 86, 87
  - slopes 88, 218
  - surface topography 216, 218
  - surface water 86
- drugs
  - donated 266
  - essential lists 266, 268
  - management 269
  - reserve stocks 280
- earthquakes, injuries 257, 286
- eating utensils 233-4
- employment
  - food production 128-30
  - remuneration 128, 129-30, 131
- environment
  - erosion 228
  - impact
    - fuel supplies 123, 234, 235, 242
    - settlements 227-9, 241
  - protection 13, 227-8

…

  - transmission 76, 77-9
- vitamins
  - A
    - deficiencies 187
    - measles vaccination 275
  - daily requirements 189
  - deficiencies 137-8, 140
  - supplies 137
- vulnerable groups
  - clothing needs 231
  - construction tasks 237
  - definitions 9-10, 57-8, 110, 210
  - economic needs 215
  - fuel supplies 235-6
  - hygiene promotion 61
  - nutritional support 142-6, 164
  - personal hygiene 232
  - protection 10-13
  - social needs 215
  - washing facilities 70, 71
  - water supplies 57-8, 66
  - people per outlet 65-6
  - quantities 63, 64
  - queuing times 63, 66
  - vulnerable groups 57-8, 66
- women
  - *see also* vulnerable groups
  - birth attendants 262
  - equal rights 12
  - gender-based violence 288, 289-90
  - health services 255
  - laundry facilities, privacy 70
  - menstruation 75, 232, 233
  - pregnant, nutrition 142
  - reproductive health 285, 288-9
  - safety
    - exploitation 40-1
    - shelter 220
    - toilets 73, 75
  - sexual coercion 37, 41, 225
    - food supplies 113
  - shelter programmes 209, 225
  - water collection 56, 66

Figure 1. Index of Humanitarian Charter and Minimum Standards

· Natural language queries can be supported by simple string matching of words from the query against the Index Ontology concepts. Figure 2 shows a blog entry posted by a New Orleans resident at the beginning of the U.S. Katrina crisis (The survival of New Orleans Weblog, http://interdictor.livejournal.com, 8:54 am, August 30th, 2005). The request in the text to receive relevant information can be viewed as a simple query posted in natural language. Simple string matching between the text and the Index Ontology can identify relevant topics such as: food/water/medicine and personal hygiene, which appear in the Index. The relevant page numbers of the index topics can supply immediate relevant information delivered in response to the query in any of the above topics. These could include a short description and possible values required to maintain minimal standards in areas such as personal hygiene. A simple Web interface could support an online connection between the blog and the Index Ontology, allowing immediate response.

· Basing the Open Ontology on the Index Ontology supplies an easy-to-understand mechanism with which most users are familiar. The skills required to utilize the ontology are minimal and can be implemented by any ontology tool, such as Protégé (Noy and Musen, 2000).

· The 'high level knowledge' represented by the Index Ontology can easily be linked to classes representing required actions such as: status updates, email notification of current crisis situation, resources required for the survivors, critical locations where immediate intervention is required. The current ontology representation already includes values that can be represented as properties such as measuring acute malnutrition in children under five years and other age groups.

· The implementation of the ontology is independent of any ontology language. It can be implemented in any currently used ontology language such as OWL/DAML and due to its simplicity can be implemented by alternative ontology languages.

· The adoption of an Index Ontology allows a flexible approach to ontology creation and adoption. As the following section describes, the ontology can be expanded using additional Index Ontologies or alternatively direct links to information on the Web.

· Finally the basic ontology and the knowledge it represents are already defined in multiple languages, allowing multiple viewpoints of similar information in multiple languages. Furthermore, it allows information in multiple languages to be directed to identical ontology concepts.

> Right now, it's a matter of survival. There are 3 important aspects to surviving this: you need food/water/medicine, you need personal protection, and you need the means to conduct personal hygiene in such a way that you're not creating more of a problem than you're solving. For any media out there reading this, it would be very helpful for you to post guidelines for survivalist hygiene.

Figure 2. Sample Blog Posting During Katrina Crisis - August 30th, 2005

RELATED WORK

Ontologies have been defined and used in various research areas, including philosophy (where it was coined), artificial intelligence, information sciences, knowledge representation, object modeling, and most recently, eCommerce applications. In his seminal work, Bunge defines Ontology as a world of systems and provides a basic formalism for ontologies (Bunge, 1979). Typically, ontologies are represented using Description Logic (Borgida and Brachman, 1993), where subsumption typifies the semantic relationship between terms.

The realm of information science has produced an extensive body of literature and practice in ontology construction, e.g., (Vickery, 1966). Researchers in the field of knowledge representation have studied ontology interoperability, resulting in systems such as Protégé (Noy and Musen, 2000). An adaptive ontology model that allows the ontology to evolve quickly during the crisis timeline is proposed here.

Previous efforts to utilize ontology for crisis response include the OpenKnowledge system, which supports and enhances the sharing and effective use of information and services among different actors (Vaccari et. al., 2006). Previous work also focused on blogs and the collaborative tagging approach (Ziesche, 2007). However, the present work takes ontology for crisis management further and enables real-time extension of the ontology.

Ontology merging has been researched from various aspects. The groundwork for ontology merging appeared in (Stumme and Maedche, 2001) which described merging ontologies following a bottom-up approach that offers a structural description of the merging process. Further ontology expansions on ontology evolution were discussed in (Noy and Klein, 2003). Improving the quality of the ontology using a transformation approach was presented in (Mostowfi and Fotouhi, 2006). In (Tolk et. al., 2007) various layered composability approaches are presented along with their derived implications and requirements for ontologies. Similar ideas are incorporated in the expanding the ontology section.

ONTOLOGY DESIGN

This section presents the ontology design process. The section first shows how concepts are extracted from predefined research presented in a book or on-line documentation to construct the ontology layout. Next, the section depicts how the ontology can be expanded and similar documents based on similar concepts can be added to the ontology. Last the section shows how the ontology can function in a multilingual environment.

Extracting the Ontology Layout

Based on the Sphere Handbook index (Sphere Project, 2004), an initial ontology can be constructed using existing hierarchical and semantic relations. Furthermore, data linking to additional information can be stored as class properties. Figure 3 displays a sample of the Index Ontology created from the Sphere Handbook index (Figure 1). The class defined as *cooking* is defined as a super-class of four subclasses: *fuel supplies*, *environmental impact*, *water supplies*, and *stoves*. However, *fuel supplies* is a subclass of two additional classes: *vulnerable groups* and *impact*. Similarly, *water supplies* is a subclass of both *cooking* and *vulnerable groups.* The properties of the class *personal hygiene* can match the class with additional information regarding hygiene in the Sphere Handbook, such as full description pages or relevant values. Additionally, external information extracted from other resources can be matched with the extracted Index Ontology.

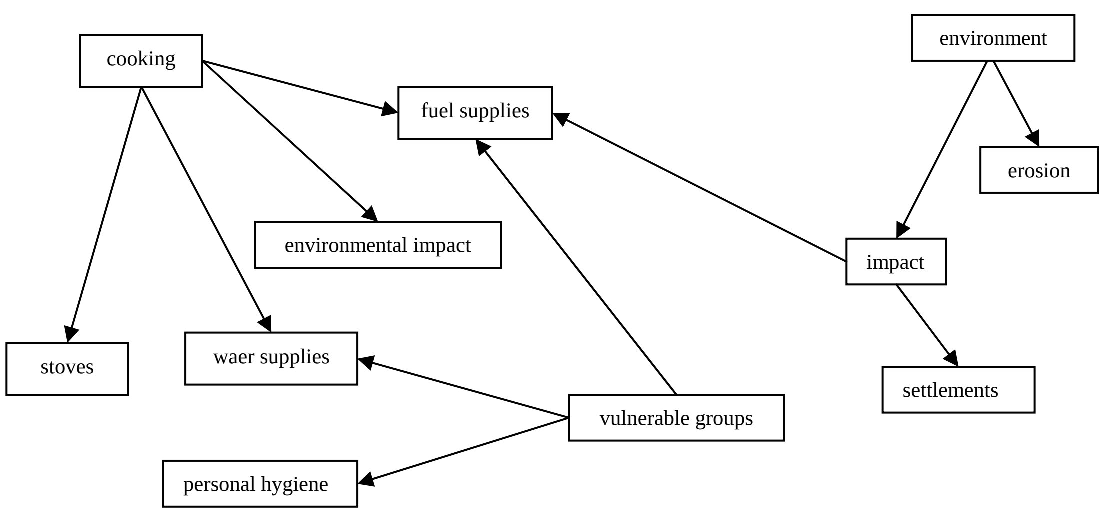

Figure 3. A Sample of the Extracted Index Ontology

Expanding the Ontology

The ontology can be expanded using external information from other resources such as additional data based on books or websites. For example, the Wikipedia web site for hygiene includes index information which could be added to the current Index Ontology using similar class definitions. Figure 4 displays index information from the Wikipedia *hygiene* index that can be used as concepts for possible ontology expansion. Notice that the concept *personal hygiene* is a subclass of hygiene according to this definition. Figure 5 displays the ontology expansion based on the Wikipedia *hygiene* entry. Alternatively, additional index books considered fundamental in the field can be added to the ontology. For example, the Merck Manual of Medical Information (Beers, 2003) index can be used for medical class expansion.

There are multiple approaches to merging ontologies such as the Formal Concept Analysis described in (Stumme and Maedche, 2001). Possible merging operations for the ontology engineer are presented in (Noy and Klein, 2003). Furthermore, (Segev and Gal, 2007) proposed using (machine generated) contexts as a mechanism for quantifying relationships among concepts. Using this model has an advantage since it provides the ontology administrator with an explicit numeric estimation of the extent to which a modification “makes sense.” The present research adopts the method of expanding the ontology based on context mechanism.

Hygiene

Contents
1. Personal hygiene
2. Food and cooking hygiene
3. Medical hygiene
4. Personal service / served hygiene
5. History of hygienic practices
    5.1 Europe
6. Grooming
7. Hygiene Certification
8. Academic resources

Figure 4. Possible Concepts Expansion Based on Wikipedia Indexing

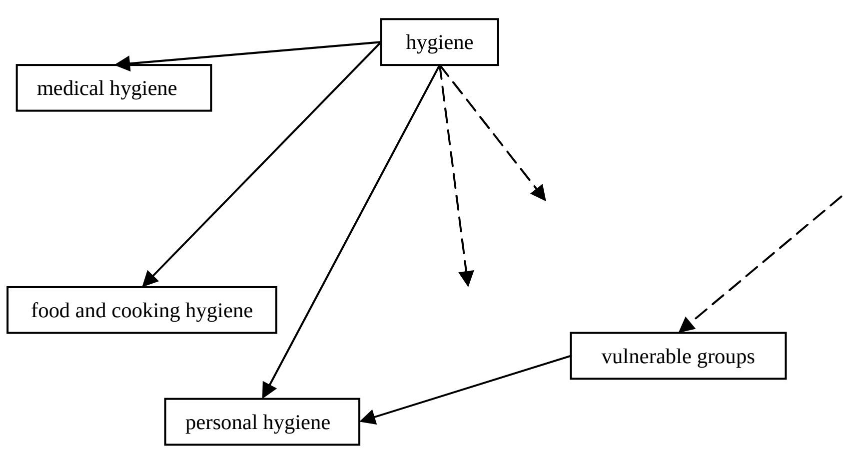

Figure 5. Ontology Expansion Based on Wikipedia

Multilingualism

The different versions of the Sphere Handbook were translated into 37 languages. Thus it supplies a top level ontology that can be used concurrently in multiple languages. Since each high level Index Ontology concept is represented in multiple languages, there is faster ontology adaptation in crisis situations.

An ontology-based model for multilingual knowledge management in information systems has been proposed in (Segev, 2008). The unique feature was a lightweight mechanism, dubbed context, which is associated with ontological concepts and specified in multiple languages. The contexts were used to assist in resolving cross-language and local variation ambiguities.

UTILIZING THE ONTOLOGY

The question arises of how the Index Ontology can support agencies and groups involved in a crisis. The answer can be divided into two separate tasks: to enable the information flow during the crisis to be matched with relevant ontology concepts and to direct the relevant information to the correct agency or individual.

Ontology Matching

The ontology matching process directs the crisis information flow to the relevant ontological concepts. The crisis might include multiple types of information such as documents, emails, blogs, and update postings in message boards. One of the difficult tasks would be matching in real-time each information datum with the correct concepts without the usual training process required in ontology adjustment and usually performed over a long period of time.

To overcome the time limitation required to process ontology for optimal information flow the following method is proposed. Let $O_1, O_2, \ldots, O_n$ be a set of ontologies, representing either the Index Ontology or each representing different domain knowledge. A simplified representation of an ontology is $O \equiv \langle C, R \rangle$, where $C = \{c_1, c_2, \ldots, c_n\}$ is a set of concepts with their associated relation ***R***.

To analyze the crisis information flow a context extraction algorithm can be used. To handle the different vocabularies used by different information sources a comparison based on context comparison will be used in addition to simple string matching. The context will be extracted for each document and then compared with the ontology concept.

The extraction process uses the World Wide Web as a knowledge base to extract multiple contexts for the textual information. The algorithm input is defined as a set of textual propositions representing the crisis information description. The result of the algorithm is a set of contexts - terms which are related to the propositions. The context recognition algorithm was adapted from (Segev et. al., 2007) and consists of the following three steps:

1. Context retrieval: Submitting each token to a Web-based search engine. The contexts are extracted and clustered from the results.
2. Context ranking: Ranking the results according to the number of references to the keyword, the number of Web sites that refer to the keyword, and the ranking of the Web sites.
3. Context selection: Finally, the set of contexts for the textual proposition, defined as the outer context, is assembled.

To evaluate the matching of the concepts with the information and its context, a simple string-matching function is used, denoted by $\boldsymbol{match_{str}}$, which returns 1 if two strings match and 0 otherwise. I is defined as the information, and D^I is the information descriptor. Also, n is defined as the size of D^I.
The match between the concept and the information is defined as the sum of the concept matching values:

$$match(I, c_j) = \sum_{t_i \in D^I} match_{str}(t_i, c_j)$$

The overall match between the ontology and the information is defined as a normalized sum of the concept matching values:

$$match(I, O_i) = \frac{1}{n} \sum_{c_j \in O_i} \sum_{t_i \in D^I} match_{str}(t_i, c_j)$$

Directing the Crisis Information Flow

The Index Ontology can serve as a knowledge base for directing crisis information flow. An information system deployed in a crisis can use the Index Ontology as an immediate knowledge representation that can be accessed by emergency forces. Civilians in a crisis can access such a system to link to relevant information or to provide real-time information that will be matched immediately with concepts predefined in the ontology.

All rescue forces will be able to utilize the Index Ontology directly or indirectly. New, uploaded information will be mapped to the relevant ontology concepts. Each rescue force will be able to include communication means which will alert them to new relevant information regarding specific concepts. Using such a mechanism, email or text messages can be delivered to handheld devices on the scene. Relevant information can be extended to include geographical information systems. Consequently, ontology concepts can be identified with geographical location resulting in concepts such as *flooding* being identified with locations in the New Orleans area.

Each on-site crisis actor can constantly update rescue and management decision making forces. The information can be automatically classified according to the ontology matching algorithm described previously. Using crisis actors who can deliver information in real-time allows the amount of accessible information to be increased at a very low information delivery cost when an automatic Index Ontology is used.

Rescue forces can supply the crisis population with relevant information according to relevant concepts. Users with Web access can select relevant information when needed. Users can always access the Sphere Handbook as default information that is specific information on limited concepts. Rescue and management forces will be able to add updates to all relevant concepts for all civilians in need.

DISCUSSION AND IMPLEMENTATION

In a crisis, people put different types of relevant information online – documents, emails, blogs, and posts in message boards. Much of this information can be channeled to real-time updates for both rescue personnel and people suffering the crisis.

The example, presented in Figure 2, is a sample blog posting from the U.S. Katrina crisis during the initial stages in August 2005. The example depicts a request for additional information relevant to personal hygiene. The blog was one of the few websites that continually supplied information during the crisis. Mapping the relevant request would identify a similar concept in the ontology itself. The Index Ontology includes a *personal hygiene* concept as a subclass of the *vulnerable groups* concept. Linking the blog request to the relevant information using relevant index pointers would allow the user to receive information relevant to the request. Figure 6 shows an immediate response that includes most of the relevant information and can be posted to supply the user with the requested relevant information to assist in the crisis.

Experiments are underway to analyze the ability to map relevant crisis information based on the Index Ontology. Blogs posted during the Katrina and South Asia earthquake crises are being used to analyze information flow based on Index Ontology.

Non-food items standard 2: personal hygiene

Each disaster-affected household has access to sufficient soap and other items to ensure personal hygiene, health, dignity and well-being.

Key indicators (to be read in conjunction with the guidance notes)

- Each person has access to 250g of bathing soap per month (see guidance notes 1-3).
- Each person has access to 200g of laundry soap per month (see guidance note 1-3).
- Women and girls have sanitary materials for menstruation (see guidance note 4).
- Infants and children up to two years old have 12 washable nappies or diapers where these are typically used.
- Additional items essential for ensuring personal hygiene, dignity and well-being can be accessed (see guidance note 5).

Figure 6. Index Ontology based response to "personal hygiene" query

CONCLUSION

The paper presents initial work in the field of developing an adaptive method for crisis ontology design. The technique extends the ontology during a crisis and tailors it to the needs of the ongoing crisis. The implementation of the ontology within an information system will allow mapping of the crisis information flow. The described Index Ontology allows multidirectional flow of data between different rescue forces, from rescue forces to the civilian population, and from the civilian population to rescue and reporting organizations. The real life crisis examples evaluated using the ontology hold promise for future crisis information flow management.

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