Context Ontology for Humanitarian Assistance in Crisis Response

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ABSTRACT

Massive crisis open data is not fully utilized to identify humanitarian needs because most of it is not in a structured format, thus hindering machines to interpret it automatically and process it in a short time into useful information for decision makers. To address these problems, the paper presents a method which merges ontologies and logic rules to represent the humanitarian needs and recommend appropriate humanitarian responses. The main advantage of the method is to identify humanitarian needs and to prioritize humanitarian responses automatically so that the decision makers are not overwhelmed with massive and unrelated information and can focus more on implementing the solutions. The method is implemented on real data from the Hurricane Wilma crisis. The use of the method in the hurricane Wilma crisis shows the potential abilities to identify the humanitarian needs in specific places and to prioritize humanitarian responses in real time.

Keywords

Humanitarian needs, humanitarian response, ontology, logic rule.

INTRODUCTION

When a crisis arises, the actual needs have to be identified before the emergency actions are taken, so as to provide proper humanitarian assistance quickly in such emergency cases. However, decision makers face the challenge of identifying the crisis needs from massive information about the crisis which may appear at once and in unstructured format. Unstructured information is un-annotated data intended only for human readable presentation. The unstructured information from different sources may also have different expressions for similar needs. For example, some people may use different food brand names to express the food needs. These issues may hinder machines to process the information automatically and transform it into useful knowledge representation that depicts the actual crisis needs.

Ontologies have been used to provide structured information which creates meaningful relationships between information resources and to allow machines to process, infer, or combine the information from different sources automatically into a consistent body of knowledge. In crisis response, ontologies can unify data from different resources syntactically and semantically. However, the related domain experts who are required to construct ontology may not be available during the crisis.

This paper presents a model for a crisis response system which provides representations of humanitarian needs and recommendations for humanitarian assistance for decision makers. In particular, this paper uses context ontology as a main feature of the system for structuring input information and uses logic rules to process the input information with the corresponding domain expert sources so as to provide humanitarian assistance to the right place while addressing the right needs.

The context ontology system proposed in this paper consists of two ontologies: the crisis identification ontology that can identify crisis impacts of the certain place and time with related actors and the crisis response sub-ontology that can utilize corresponding crisis response sources. Using these ontologies and logic rules, the context ontology system can automatically propose the possible humanitarian responses based on the actual needs.

The rest of the paper is organized as follows. The next section provides related work, followed by the section on the design of the context ontology model. Then the implementation aspects of the system model are discussed. Last, the conclusion and further research are presented.

RELATED WORK

Ontology and Context

Ontology is defined as an explicit and formal specification of a conceptualization (Gruber, 1993). Ontology consists of a list of terms and their relations to represent the domain. Ontology has been used to provide shared and common understanding of a domain so that it can facilitate interoperability among information systems and also share and reuse knowledge among systems.

Ontology can be built either from scratch or by reusing existing ontologies and updating them for the current need. Some previous works study building ontology from scratch (Belleau et al., 2008; Khan and Luo, 2002; Pinto and Martin, 2004). However, the method of building a proper ontology is still an open issue depending on its domain.

While ontologies are considered a result of a manual effort of modeling a domain, contexts are system generated models (Segev, 2005). Contexts in ontology entities are defined as a semantically consistent body of information in which the entity makes sense (Cafezeiro et al., 2008). Contexts can also be used to verify relationships among ontology concepts (Segev and Gal, 2006).

Ontology in Crisis Response

In crisis responses, ontology has been used in several ways. Di Maio (2007) addresses open ontology methodology for open source emergency response systems. Open ontology allows users and developers to collaboratively and dynamically create and support knowledge and semantic consistency for emergency response systems, as opposed to closed ontology, whereby the ontology is developed by an organization to impose a single view of the world without a public consultation process and deliverable to the public.

Li et al. (2008) propose a practical emergency response workflow and emergency response ontology architecture. In their paper, the proposed ontology's goals are to standardize semantic concepts that can be applied to many different emergency response systems and to define practical common vocabularies between emergency response personnel.

Fan and Zlatanova (2011) explore the semantic interoperability of the terms and spatial information to be used by different emergency response communities. The proposed model is composed of dynamic data ontology, which will be linked to corresponding disaster ontology, and of static data ontology, which includes various types of ontologies from different ontologies that can assist responders in decision making, such as spatial ontology, responders ontology, etc.

Truptil et al. (2008) develop a meta-model of crisis situations by using ontological links to integrate and support interoperability of heterogeneous information systems which are used by each emergency responder. Furthermore, the paper states that knowledge about crisis contexts allows the specific situation to be modeled and crisis ontology to be characterized.

However, aforementioned previous works did not aim at creating a solution to bridge between the emergency needs and the crisis response actions using an ontology merging process to represent the knowledge and rule based techniques to support the decision making process.

CONTEXT ONTOLOGY SYSTEM FOR CRISIS

To harness the mass information from humanitarian open data, input data need to be transformed into useful information for the decision makers and the system needs to be updated to reflect the current situation. The manual processing of all information is impractical because considerable time and manual resources are required. A crisis response system should process the information and assist in providing rapid response in a short period of time. In particular, when a disaster occurs, the system captures related information and relevant context automatically and delivers its recommended responses for decision makers to choose. The following model represents the proposed context ontology system for crisis.

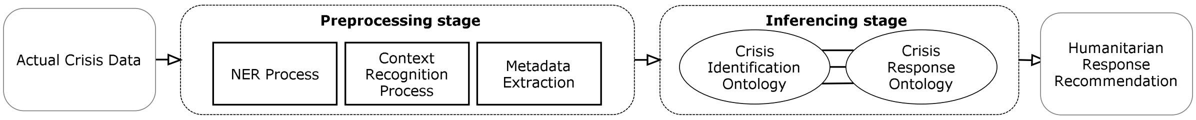

Figure 1. Context Crisis Ontology System

The proposed system, displayed in Figure 1, consists of two main parts: Crisis Identification Ontology and Crisis Response Ontology. Crisis Identification ontology is composed of two parts: the global part which contains predefined static concepts and the local part which contains dynamic concepts that can be continuously updated according to current situations. For instance, the global ontology may include class “Crisis Needs“ which covers all possible humanitarian needs which can be used as range domain of property “impact”. The local part, conversely, includes the information about specific events which have occurred in a certain place with their crisis impacts. These ontologies will be described in detail in the following sections of this paper.

Crisis Identification Ontology

The main purpose of Crisis Identification Ontology is to assist in the categorization of the crisis information based on the existing domains. Crisis Identification Ontology consists of two sections: the global part and the local part. The global part of the ontology can be applied regardless of the type of crisis. While the global part of ontology remains static during the event, the content of the local part can be changed continuously during the flow of crisis information. The benefits of using the global part of ontology are to support ontology reuse and to reduce ontology construction time.

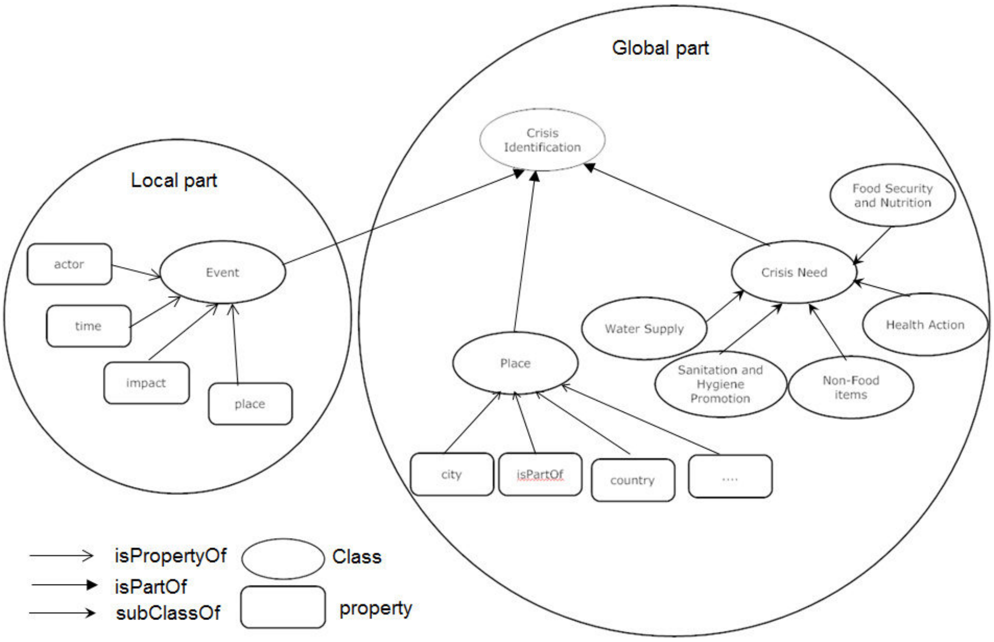

Figure 2. Crisis Identification Ontology

Figure 2 exhibits several classes in Crisis Identification Ontology. Class “Crisis Need” and class “Place” are categorized as in the global part because they can be constructed using a generic data source such as DBpedia and the Sphere Handbook. DBpedia is the community-driven data pool that structures data from Wikipedia. DBpedia relies on the existing Wikipedia community to update the content. To keep its knowledge base up-to-date according to the Wikipedia knowledge base, DBpedia has two extraction frameworks, dump-based data extraction and live extraction workflows (Bizer et al., 2009). There are some applications which have been publicly available using DBpedia identifiers, such as Zemanta (http://www.zemanta.com) and Faviki (http://faviki.com). The Sphere Handbook (Sphere Project, 2011) has been designed to aim at improving both the agencies’ quality of humanitarian assistance and their accountability to their constituents, donors, and affected populations. The Sphere Handbook is one of the most widely known and internationally recognized sets of common principles and universal minimum standards in humanitarian response areas. It should be noted that the global part of Crisis Identification Ontology is a set of predefined concepts that have been constructed before the crisis occurs and it can be expanded by adding other disaster recovery resources.

Relations of the class "Crisis Need" and its subclasses come from the Sphere Handbook's table of contents. Class "Place" has several properties such as city, country, etc., where these properties come from DBpedia properties. Each class of the global part of Crisis Identification Ontology will be used as data references for later use. For example, class "Crisis Need" and its subclasses will be used as reference to identify humanitarian needs of extracted terms. Another example is property "isPartOf", which will be used to expand the place of an event into the bigger scope of area.

The local part contains the dynamic data based on the actual crisis data flow. We define the class "Event" to capture current crisis situation. Event class includes at least four properties: "actor", "time", "place", and "impact".

Property Name	Description
Actor	People within the crisis occurrence place who are involved with the crisis event. The report about these actors may come from actors themselves or people who are related to them.
Time	Time indication about when the report was submitted
Place	Location which indicates where the crisis impact occurred.
Impact	String description about what the main message of the event is.

Table 1. Properties of Class "Event"

When a textual document which contains crisis information enters the context ontology system, the system will preprocess it by extracting required information and transforming it into one instance of class "Event". To acquire all required information needed for properties of class "Event", several approaches are applied, such as the Name-Entity Recognition (NER) process for extracting place and actor information of the document, the context recognition algorithm for eliciting impact information, and the document metadata extraction for time information which describes when the document was created.

Crisis Response Ontology

To make the initial ontology, indexes from the Sphere Handbook and the chapter structures can be extracted to build hierarchical and semantic relations (Figure 3). Each index will be an ontology class. For example, index "Water Supply" will become class "Water Supply" which has relations with class "PoUWT" (Point-of-Use Water Treatment), class "Safe Drinking Water", class "Water Collection Points", and class "Toilet". Figure 4 shows the Crisis Response ontology produced from the aforementioned data resources.

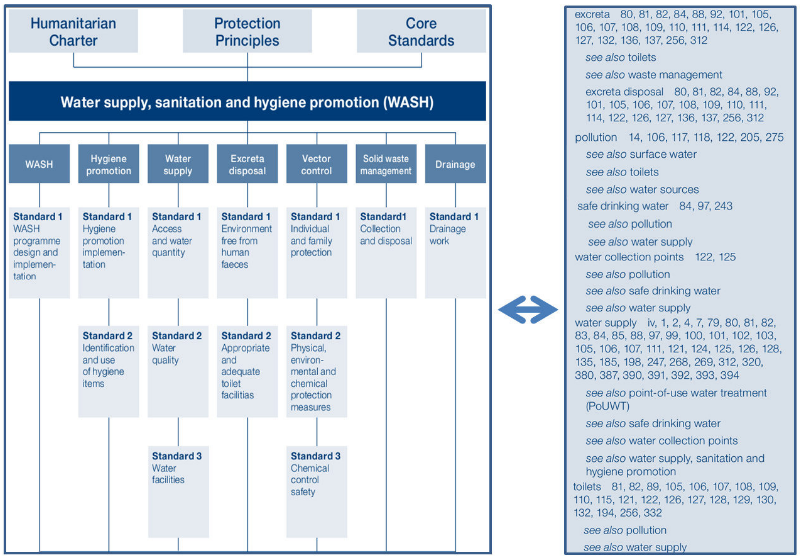

Figure 3. Chapter Structure and Index of Humanitarian Charter and Minimum Standards

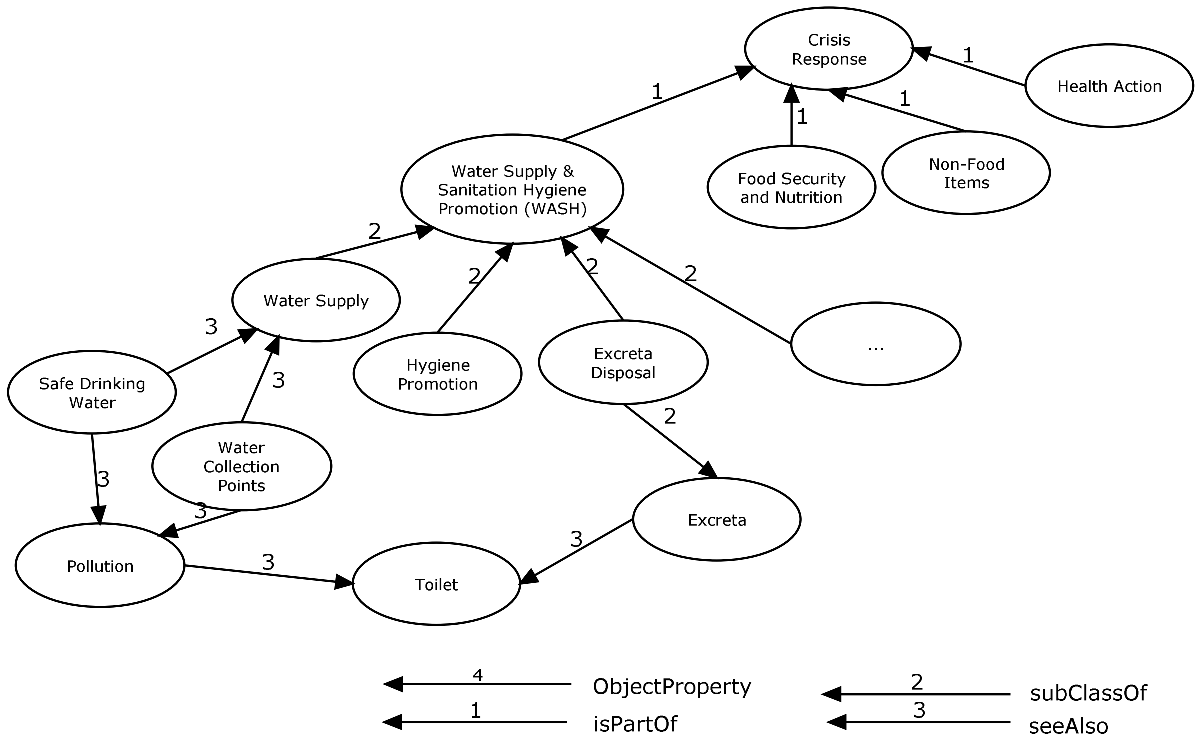

Figure 4. Crisis Response Ontology Class

Each of these Crisis Response Ontology classes will have class properties which consist of the Sphere Handbook page number and the predefined values from the page (Figure 5). For example, class "Water Supply" has many related pages that describe in detail requirements of humanitarian assistance such as requirement of average water use for drinking, cooking, and personal hygiene and maximum distance from any household to the nearest water point.

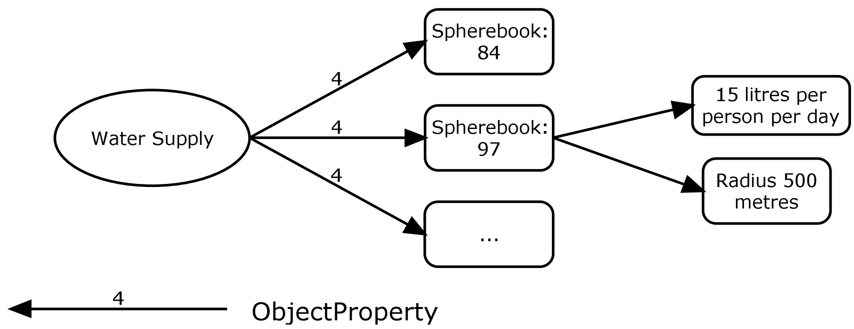

Figure 5. A Context Ontology Class and Its Properties

Context Crisis System Description

The context crisis system takes actual crisis data as the initial input. Actual crisis data are textual documents which can be obtained from blogs, emails, or other open data on the Internet. Each document is regarded as one dataset which later on will be preprocessed for the system input.

Preprocessing actual crisis data into input data for the system requires three kinds of processes: Name-Entity Recognition (NER) process, context recognition process, and metadata extraction.

The NER process refers to the extraction of words and strings of text within documents that represent discrete concepts, such as names and place. There are various tools and methods that can be chosen to do NER processes, such as LingPipe NER system (Baldwin and Carpenter, 2003), ESpotter (Zhu et al., 2005), etc. Through the NER process, the required Actor and Place information from a document can be obtained.

The context recognition process refers to the process of identifying the important contexts of documents from an actual crisis datum which relates to the humanitarian need. As a first stage of the context recognition process, the actual data will be processed into a set of terms using the C-Value algorithm (Frantzi et al., 2000). Piao et al. (2010) evaluate five term extraction algorithms in a certain domain. In their evaluation, the C-Value algorithm is the one which has the best performance in automatic extraction of concepts from input texts.

After the set of terms is obtained using the C-Value algorithm, the contexts of each term can be recognized by using the context recognition algorithm. In this algorithm (Segev, 2005), the contexts of each term are obtained by using the Internet, which is used as a context database, and then ranked. Using the Internet as a context database has several advantages: use of the Internet doesn't require the constant updating and maintenance of the database and also use of the Internet offers access to unlimited knowledge domains that are continuously being updated. Each term will be regarded as a query to an Internet search engine. The preliminary contexts of each term are obtained by performing the term frequency method on the web pages retrieved.

To determine humanitarian needs from a document, the extracted terms of that document need to be mapped into the global part of the Crisis Identification Ontology. Let d_i be extracted terms of a document and $D = \{d_1, d_2, \ldots, d_i\}$ be a set of textual descriptors representing a documents where all d_i has set of contexts $X_i = \{x_1, x_2, \ldots, x_p\}$ which describe all possible scenarios. To map the extracted terms into Crisis Identification Ontology, the string matching function between the terms' contexts and ontology's concepts is used. The function is denoted by $match_{str}$, which returns 1 if two strings match and 0 otherwise. Let $O=\langle C,R\rangle$ be a simplified representation of an ontology where $C=\{c_1, c_2, \ldots, c_n\}$ is a set of concepts with their associated relation R. The match between terms' context and ontology is defined as follows:

$$Match\ (d_i, O) = \sum_{x_p \in d_i} \sum_{d_i \in D} \sum_{c_n \in C} match(x_p, c_n)$$

If the contexts are matched with any classes in the global part of Crisis Identification Ontology, those classes will be recognized as required humanitarian needs which represent that document. The results of the combination of the result of the context recognition process (the main message of humanitarian needs of a document) with the result of the NER process (actor and place information from a document) and with metadata of the time when that document is created will be the properties of an instance of class "Event" which describes a crisis event in a specific place with specific humanitarian needs.

By using a set of predefined logic rules, the context ontology system will process instances from class "Event" and will infer corresponding responses from the Crisis Response Ontology. The logic rules mechanism has three functions: to enable the system to automatically derive recommendation statements from a set of premises/ facts, to provide explanations of how recommendations are made, and to bridge between the Crisis Identification Ontology and the Crisis Response Ontology. The decision makers are able to prioritize actions according to their perspective and limitations.

Figure 6 shows the general inference logic rules of context ontology. Rule r1 will map instances of class "Event" to Crisis Response Ontology classes by matching the impact of that instance and the corresponding class in the Crisis Response Ontology. This is possible since both impact and classes are derived from same resource: the Sphere Handbook. Rule r2 and rule r3 make deeper inference into Crisis Response Ontology by obtaining all related classes and matching them with the actor, place, and time information so that the possible actions of responding to an impact can be known. seeAlso(?r.?r') are vocabulary/properties derived from the Sphere Handbook corpus. Rule r4 infers the elapsed time between created time of the report and current time when the rule is executed. Rule r5 and rule r6 aggregate the possible actions which happened in the same place and calculate the weight of those possible actions. The more possible actions appear, the bigger the weighting score is, which means that a possible action type is more prominent than others. Finally, using a weighting factor and threshold of each possible action type, rule r7 will infer recommended actions and their priority, when these recommendations will be delivered to decision makers. The threshold of each possible action is determined by decision makers and may vary based on the type of crisis. For example, for the hurricane crisis, water need is more important than food need, so that the decision maker will decide to lower the threshold for water supply support and raise the threshold for food support. Since the goal of these rules is to optimize support efforts, by addressing the major problems which have high priorities, the logic rules will eliminate the unnecessary possible actions in order to promote an effective decision making process.

r1: type(?e, Event), impact(?e, ?i) → response(?i)

r2: response(?r), seeAlso (?r,?r') -→> responseProperties(?r',?prop)

r3: responseProperties(?r,?prop), place(?e, ?p), elapsedTime (?e, ?et), actor(?e, ?a) → possibleAction(?r, ?pa)

r4: time(?e, ?t), currentTime(?t') → elapsedTime (?e, ?t'-?t)

r5: place(?e_1, ?p_1), place(?e_2,?p_2), sameAs (?p_1,?p_2) → samePlace(?e_1, ?e_2)

r6: possibleAction(?r_1, ?pa_1), possibleAction(?r_2,?pa_2), sameClass(?r_1,?r_2), samePlace(?r_1, ?r_2) → weight(?pa, ?w)

r7: possibleAction(?r,?pa), weight(?pa, ?w), threshold(?pa, α) → recommendedAction(?ra, ?priority)

Figure 6. Inference Rules of Context Ontology

IMPLEMENTING CONTEXT ONTOLOGY: CASE STUDY OF HURRICANE WILMA

Hurricane Wilma was chosen as the study case of this paper because it was a multinational crisis in which a massive amount of information came out in a short period of time. Hurricane Wilma is one of the most intense hurricanes to occur in the Atlantic Basin. Hurricane Wilma formed on October 15, 2005 and dissipated on October 26, 2005. It affected a wide area, including Cuba, Jamaica, Honduras, the Bahamas, Florida, etc.

The actual crisis data of the Hurricane Wilma may come from blogs, community sites, or news websites. The following report (Figure 7) is taken from bbc.co.uk and describes actual crisis conditions of the people in that time.

My sister and her husband are amongst 1,000 British tourists that have been abandoned by their travel companies, and are currently in a car park somewhere in Cancun. These people have no running water, no toilets, no food, no clean clothes, and have no idea what is happening to them, and when they are going to be able to come home. What is being done to help them?
Adam Norris, Chichester

Figure 7. Sample Post during the Crisis of Hurricane Wilma - 28 October 2005 (Retrieved 20 March 2012)

After the data was preprocessed by the NER process and context recognition system, an instance, named ev1000001, of class Event is created (Figure 8). To address event instances, the system infers the possible actions from the Crisis Response Ontology. If the property "impact" of an instance is related to the need of "water supply", for instance, the system will derive the class "Water Supply" from Crisis Response Ontology using rule r1. In this case, the system will derive response of general classification of water supply needs (the response will cover the basic survival water needs which contain drinking water, water for cooking needs, and water needs for hygiene practices). If input data mention more specific information about the water supply needs. For example, drinking water needs, then using rule 2, the system can infer the response for sub-classification of class "Water Supply" in Crisis Response Ontology which is "Safe Drinking Water". By referring to property of class "Water Supply" (Figure 5), the actors, place, and elapsed time using rule r3, the system can infer possible actions for that event, such as the amount of basic survival water needs and distribution point radius (500 metres). Combining data from other instances and DBpedia property such as areaTotal and populationTotal of a certain place, the total amount of basic survival water needs for the entire population in that area can be obtained (9,424,590 litres per day) and the total water distribution points for that place can be determined. This aggregation can help decision makers to send humanitarian needs in bulk effectively and efficiently. In addition, we can get an overview of humanitarian needs distribution to evaluate the effect of that crisis.

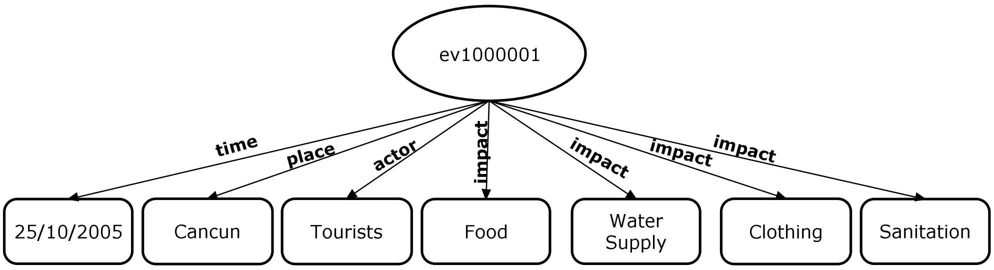

Figure 8. Instance of Class "Event"

Using our approach, we analyzed a dataset of 125 textual reports from a social media blog in bbc.uk where people voluntarily gave the information about what was happening during the Hurricane Wilma crisis. These data are selected because they can represent actual crisis impacts and crisis recovery needs from the field report perspective. If there are duplicate data coming from the same person and reporting the same things for the same place, the simple algorithm can be used to check and eliminate them. If the data come from a different person but report similar things for the same place, the possible response actions will be given more weight (which means it will have a higher priority) using rule r6.

If the data from social media often provide a field report, which is a live report which contains more detailed information of an occasion during a crisis, from each person who contributed, the data from the news media often provide the summary or the general information of the crisis event. When decision makers receive news data, such as the number of people who are migrating during the crisis, from other sources, they can tune up the Crisis Identification ontology by creating an instance which contains the updated number of the affected people in class "Place". Later on, the system can use this updated information to infer new possible actions for decision makers.

Using Google maps, the places which have specific icons such as food icon, water supply icon, or debris removal icons indicate there are needs for humanitarian assistance for those places. The bigger the icons are, the greater the priority the need has. Figure 9 exhibits the humanitarian response needs for the specific areas of Cancun, Cuba, Cayman Islands, and Florida.

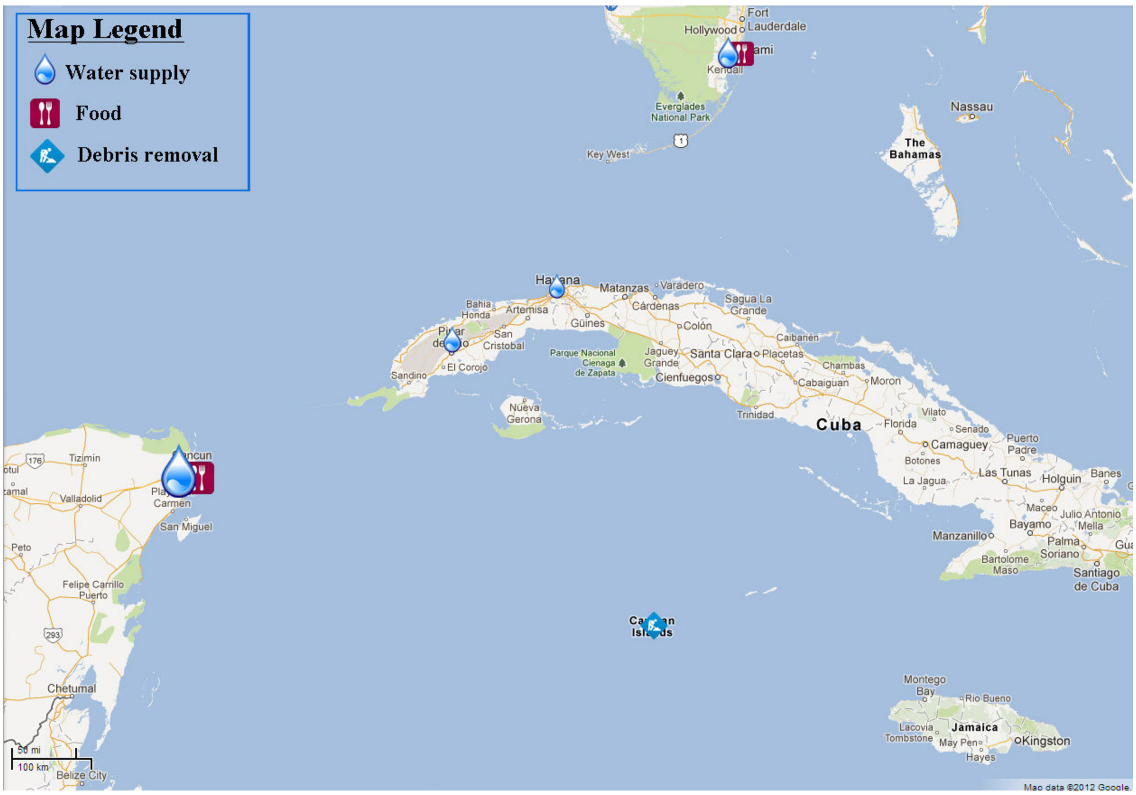

Figure 9. Distribution Map of Humanitarian Needs

Table 2 displays more examples of humanitarian needs in various places during Hurricane Wilma. The numbers beside the type of needs indicate the priority of humanitarian needs for response. Humanitarian need with number (1) means it has highest priority. These priorities come from the weights of each possible action needed to assist the corresponding humanitarian needs.

No	Place	The Humanitarian Needs and Its priority
1	Pinar del Rio	Water Supply(1), Drainage(1), Excreta Disposal(1), Settlement(1)
2	Havana	Water Supply(1), Drainage(1), Excreta Disposal(1), Settlement(1)
3	Cuba	Debris Removal (1)
4	Florida	Water Supply(1), Debris Removal (2), Food(2)
5	Cancun	Shelter (1), Water(1), Food(2) , Clothing (3), Toilet(3), Drainage (4)
6	Isla Mujeres	Water Supply(1), Clothing (2)
7	Jamaica	Debris Removal(1), Flood Recovery(1), Shelter(1)
8	Miami	Water Supply (1), Debris Removal(2), Food(2)
9	Rio Yucatan	Shelter(1)
10	Cozumel	Debris Removal(1), Flood Recovery(1), Shelter(1)
11	Playa Del Carmen	Water Supply(1)
12	Isla Hobox	Debris Removal(1), Food(1), Water Supply(1)
13	Riviera Maya	Water Supply (1)
14	Puerto Morelos	Water Supply(1)
15	Panama City	Shelter(1)

Table 2. The Examples of Various Humanitarian Needs and Their Priorities

CONCLUSION

In this paper we present the context ontology system which transforms the textual crisis data into the sets of response recommendations for decision makers. The context ontology system, as a decision support tool, utilizes existing domain expert resources, such as DBpedia and Sphere Handbook, to process the actual crisis data and represent the humanitarian needs in the specific areas with recommended actions and their priorities in the response to the needs.

The system consists of two ontologies, Crisis Identification Ontology to determine the humanitarian needs from the input data and Crisis Response Ontology to determine the response recommendations for the actual humanitarian needs. A set of logic rules is used to unify these two ontologies and to automatically generate the output, humanitarian response recommendations, and to provide the decision maker with the explanations of how the system infers the recommended actions. Using existing geospatial services such as Google Maps, the system can represent the needs of humanitarian assistance with a map to help decision makers to identify the impact area and prioritize the prominent recommended actions.

Experiments to analyze the feasibility of the method implementations in different crisis cases are currently underway. Further development and collaboration with decision making practitioners are also needed to evaluate the effectiveness of the system and to prepare the system for a new real crisis event. Another direction of future work is to expand the model to include logic rules for the hierarchical chain of command of the emergency response team so that the information generated from the system can be delivered to the relevant person in charge according to the information type and authority power to make decisions.

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REFERENCES

1. Baldwin, B. and Carpenter, B. (2003) LingPipe, available from World Wide Web: http://alias-i.com/lingpipe/.
2. Belleau, F., Nolin, M. A., Tourigny, N., Rigault, P. and Morissette, J. (2008) Bio2RDF: Towards a mashup to build bioinformatics knowledge systems, *Journal of Biomedical Informatics*, 41, 706-716.
3. Bizer, C., Lehmann, J., Kobilarov, G., Auer, S., Becker, C., Cyganiak, R. and Hellmann, S. (2009) DBpedia - A crystallization point for the Web of Data. *Web Semantics Science Services and Agents on the World Wide Web*, 7, 154-165.
4. Bloodsworth, P. and Greenwood, S. (2005) COSMOA an ontology-centric multi-agent system for coordinating medical responses to large-scale disasters, *AI Communications*, 18, 3, 229-240.
5. Cafezeiro, I., Rademaker, A. and Haeusler, E.H. (2008) Ontology and context, *Proceedings of CoMoREA 08*, 53–62.
6. Di Maio, P. (2007) An open ontology for open source emergency response system, *Open Source Research Community*, January 2007.
7. Fan, Z. and Zlatanova, S. (2011) Exploring ontologies for semantic interoperability of data in emergency response, *Applied Geomatics,* 3, 109–122.
8. Frantzi, K., Ananiadou, S. and Mima, H. (2000) Automatic recognition of multi-word terms: The C-value/NC-value method, *International Journal on Digital Libraries*, 3, 115-130.
9. Gruber, T. R. (1993) Toward principles for the design of ontologies used for knowledge sharing, *Formal Ontology in Conceptual Analysis and Knowledge Representation*, 43, 907-928.
10. Khan, L., and Luo, F. L. F. (2002) Ontology construction for information selection, *14th IEEE International Conference on Tools with Artificial Intelligence 2002 ICTAI 2002 Proceedings*, 122-127.
11. Li, X., Liu, G., Ling, A., Zhan, J., An, N., Li, L. and Sha, Y. (2008) Building a practical ontology for emergency response systems, *2008 International Conference on Computer Science and Software Engineering*, 4, 222-225.
12. Piao, S., Forth, J., Gacitua, R., Whittle, J. and Wiggins, G. (2010) Evaluating tools for automatic concept extraction: A case study from the musicology domain, *Digital Futures*, 10, 1-3.
13. Pinto, H. S. and Martins, J. P. (2004) Ontologies: How can they be built*?, Knowledge and Information Systems*, 6, 441-464.
14. Segev, A. (2005) Identifying the multiple contexts of a situation, *Proceedings of IJCAI-Workshop Modeling and Retrieval of Context (MRC2005)*, 118-133.
15. Segev, A. and Gal, A. (2006) Ontology verification using contexts, *Proceedings of ECAI-Workshop on Contexts and Ontologies: Theory, Practice and Applications.*
16. Truptil, S., Benaben, F., Couget, P., Lauras, M., Chapurlat, V. and Pingaud, H. (2008) Interoperability of information systems in crisis management: Crisis modeling and metamodeling, *4th International Conference on Interoperability for Enterprise Software and Applications IESA 2008,* K. Mertins, R. Ruggaber, K. Popplewell, and X. Xu, (eds.), Springer, 583-594.
17. Zhu, J., Uren, V. and Motta, E. (2005) ESpotter: Adaptive named entity recognition for web browsing, *Professional Knowledge Management*, 3782, 518-529.