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ONTOLOGY STRUCTURE OF ELEMENTS FOR WEB-BASED NATURAL DISASTER MANAGEMENT SYSTEMS

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Abstract

Recent natural disasters have brought forth the need for disaster preparedness, planning, and management. Hurricane Katrina demonstrated the usefulness of websites in dealing with a natural disaster. However, little is known about the necessary contents and structures of web-based information management for natural disaster preparation. In this paper, we focus on developing the ontology structure of elements for web-based disaster management systems. We provide a comprehensive review of the existing semi-structured data representation technologies and select the appropriate set for developing and representing the ontology structure. Web elements are identified based on the grounded theory approach using an inventory of 100 non-profit disaster websites and their numerous webpages. The selected technologies are used to organize the ontology structure and the results are coded into a web-based system tool (WB-OS) that makes the ontology structure accessible on the web. Such ontology structure of web elements is utilized to evaluate the quality and completeness of current websites.

Keywords: Disaster management, natural disaster, web-based information systems, semi-structured data, grounded theory

Motivation and Research Questions

The use of the web in disaster recovery efforts demonstrated the usefulness of websites in dealing with a disaster. The Internet with its ubiquity and asynchrony is a natural platform for information exchange and communication for managing mass crisis. Although there are many disaster-related websites, little is known about the necessary contents and structures of web-based information systems for natural disaster management.

The purposes of the dissertation are in two folds. The first half is to develop the ontology structure of web elements for web-based natural disaster management systems (WB-NDMS). Ontology is “an explicit specification of a conceptualization (Gruber 1993, p. 199)”. The main idea of ontology is to share knowledge and promote reuse (Gruber 1993; Noy and McGuinness 2001). In this research, we group and define web elements in WB-NDMS and identify the relationship among them in a hierarchical manner. Second, such ontology structure of web elements is utilized to evaluate the quality and completeness of current websites. Thus, this research is attempting to answer the following research questions:

1. What are the suitable data representation approaches for developing the ontology structure of web elements in WB-NDMS?
2. What are the web elements and their ontology structure for WB-NDMS?
3. Can the ontology structure of web elements for WB-NDMS be implemented online by creating a web-based tool that shows the details of web-based ontology structure (WB-OS)?
4. How to evaluate the nature and completeness of WB-OS? How to improve it?
5. Are all web elements of equal importance? If not, how to weight their significance?
6. Could WB-OS be utilized as an evaluation tool to examine existing WB-NDMS in terms of quality and completeness?

Currently, the first three questions have been partly addressed for the first two stages of disaster management—general preparation and preparation for a given disaster—as explained later. The potential contribution of this research is to identify an accessible and comprehensive ontology structure for creating WB-NDMS to assist organizations, managers, and individuals, who are involved in disaster management. This work also shows how the synthesis of ontology, grounded theory, and semi-structured data representation technologies could make it possible to identify and code the ontology structure of web elements for a complex and large domain. Furthermore, this work demonstrates that WB-OS could be used as an evaluation tool to evaluate the quality and completeness of natural disaster management websites.
Background

In the context of organizational crisis, Pearson and Mitroff (1993) suggest that there are five phases in a disaster: signal detection, preparation/prevention, containment/damage limitation, recovery, and learning. For natural disasters, however, signal detection and preparation should take place in the same phase. Therefore, we argue that the management of a natural disaster involves the following five stages. (1) The first stage involves general preparation for various natural disasters. (2) In the second stage, a given disaster is predicted and specific plans should be put into place. (3) The third stage is when the disaster is in progress. (4) Recovery begins immediately after a disaster, including a wide range of activities such as process restoration and individuals’ health recovery. (5) Finally, the lessons learned from current disaster should be assimilated as a practice for the refinement of general preparation for the next round.

Based on this five-stage framework, ontology structure of web elements will be constructed and categorized for each stage. Web elements are critical in developing web-based systems to deal with various stages of natural disasters. Web elements are the features, components, and information used to create websites. In the context of e-commerce website, Song and Zahedi (2005) identified web elements by using a grounded theory approach and categorized them. These categories have been used to develop a theoretical foundation for the connection between web elements and beliefs (Song and Zahedi 2001; Song and Zahedi 2005). Web elements for WB-NDMS are numerous and are far more complex than those in e-commerce. Furthermore, there has been little attempt in conceptualizing these elements. Therefore, there is a gap in the knowledge about the nature, structure, and categories of web elements for developing WB-NDMS. Our study is the first to address this gap.

Review of Data Representations Models and Choice of Technologies

Semi-structured data management has emerged in response to the following needs. First, data types with less rigid structures, such as web traffics, are on the rise. Second, issues related to data integration arise when data are combined from several heterogeneous sources (Abiteboul et al. 1997). The issue of data integration is of importance in the study since following the grounded theory approach, we need to constantly identify, compare and categorize new web elements as we investigate various websites and their numerous webpages. Furthermore, the data representation of web elements in WB-NDMS should be flexible and extendable. To develop the ontology structure, we need to choose one of the data modeling techniques (such as XML, OEM, or Lore’s XML) to describe web elements and choose one of the schema representations (such as DTD, S3-Graph, DataGuides, XML Schema, or DOM) to capture the structure. Thus, any combination of techniques that allows the transformation from data instance representation to schema representation could work. After an extensive review of literature and evaluation of advantages and disadvantages of available technologies, a combination of three technologies XML + DOM + XML Schema is selected to develop the ontology structure of web elements for NDMS.

Research Methodology

To identify web elements of NDMS, the constant comparison approach in the grounded theory is utilized on data from an inventory of 100 disaster management websites, collected from various government agencies and non-profit organizations. Grounded theory is “the discovery of theory from data” (Glaser and Strauss 1967, p. 1). It involves an iterative process between data collection and analysis through contrasting and comparing findings at each stage with those of the next. We deployed the grounded theory approach in an interpretive manner. To handle the complexity of these elements, we develop the ontology of web elements in a hierarchical structure. In ontology, we define terms and vocabulary of a domain and identify the relationship among them. In this research, we group and define web elements in WB-NDMS and identify the relationship among them, hence creating an ontology structure for the web elements.

Development of the Ontology Structure

Noy and McGuinness (2001) provide a seven-step guideline to design an ontology: (1) determine the domain and scope of the ontology, (2) consider reusing existing ontologies, (3) enumerate important terms in the ontology, (4) define the classes and the class hierarchy, (5) define the properties of classes—slots, (6) define the facets of the slots, and (7) create instances. The focus of the first four steps is to develop an ontology structure, while the last three implement the ontology with instances. Thus, the first four steps were used to develop the ontology structure for web elements. There is no reported structure or ontology for web elements in WB-NDMS; therefore, we had to enumerate important terms and categorize web elements from scratch. Based on the grounded theory, the following procedure was applied for identifying instances of web elements, categorizing them into web elements, and identifying the relationships among the web elements. The instance of web elements and their relationships were modeled using XML and DOM. The DOMs were compared and contrasted in order to allow for the XML schemas to emerge, which were visualized using DOM.
Step 1: Access the first website.

Step 2:

Step 2-1: Access a webpage of the site.
Step 2-2: Identify information on the page as instances of web elements and model them using XML and represent them in the graphical data model DOM. Add the XML and DOM to the inventory.
Step 2-3: Similar web elements are found in the inventory, compare and contrast them, and allow an XML Schema to emerge as the result of the comparison and use DOM to show the structure of the schema. Replace the two compared and contrasted XMLs with the emerged XML Schema and the corresponding DOM.
Step 2-4: Obtain another webpage of the site if any and repeat Step 2-2 to 2-3.
Step 3: Obtain the next website if there is any and repeat Step 2-1-2-4 until all elements in the websites are analyzed.

The Step 2-2 corresponds with stages of enumeration of terms and defining classes in ontology development. Furthermore, Step 2-2 accomplishes the categorization phase of the grounded theory. Step 2-3 corresponds with the development of class hierarchy in ontology development and accomplishes comparison and further categorization phase in the grounded theory. Step 2-4 accomplishes the “constant” aspect of the comparison in the grounded theory, which requires continuation of process and building from additional data and evidence. Figure 1 shows a result of constructed ontology structure of web elements for the Supplies Kit Preparation category in general preparation stage.

We have also used the selected technologies in coding the ontology structure and making it available as a web-based tool called Web-Based Ontology Structure (WB-OS). Our WB-OS tool could be navigated at different levels of details. It provides a useful resource for those who are involved in developing WB-NDMS. General understanding of disaster preparedness can be viewed by browsing upper levels of the tree, while deeper knowledge can be built by traversing more deeply through multiple levels of the tree. Currently, ontology structure of web elements for the first two stages, general preparation and preparation for a given disaster, of disaster management has been implemented in our tool. This tool is accessible on the web. Figure 2 is a snapshot of WB-OS, which was implemented on our Website, displaying a portion of ontology structure for the general disaster preparation.

Figure 1: Ontology Structure for “Supplies Kit Preparation” Based on All Websites

Figure 2: A Portion of Ontology Structure in Our WB-OS
Improvements on Ontology Structure of Elements

As structured, the ontology is flexible and extendable. It is expected to continuously evolve as new web elements emerge and has the potential to become a collective knowledgebase of web elements for disaster management. Since the ontology structure of elements of WB-NDMS will be constructed through grounded theory from a collection of natural disaster management websites, the coverage of concepts and relationship in the structure might not be complete due to the limitation of data inventory. Thus, Delphi technique (Lindstone and Turoff 1975) will be applied to obtain new elements being suggested from domain experts. Through several Delphi rounds, a comprehensive ontology structure of web elements will be created by merging these new elements with our ontology structure from grounded theory. During the same processes, the domain experts will also be asked to rate the importance of all elements in the first N levels of ontology structure.

Ontology Structure of Elements as Evaluation Tool

Based on the importance of all elements obtained from domain experts, we will use the Analytic Hierarchy Process (AHP) (Saaty 1980) to identify an overall score of a website, assigning weights by the relative importance of all elements in the ontology structure hierarchy. By judging the quality and existence of elements on the existing websites (e.g. WB-NDMS administrated by 50 states), overall scores toward structural completeness and quality of these sites would be obtained through pairwise comparison analysis with weights of elements in AHP.

Conclusion

This dissertation has six research questions. The first question is related to the choice of appropriate technology for managing the large and complex structure of web elements needed for creating WB-NDMS. Our survey and evaluation of existing semi-structured data modeling and schema representation technologies led to the choice of the XML + DOM + XML Schema technologies for the discovery, modeling, and implementing the ontology structure for web elements needed in WB-NDMS. The second research question is related to the identification of the web elements and ontology structure for WB-NDMS. By combining the grounded theory approach and the selected technologies, we have developed the process to identify and categorize the WB-NDMS web elements into a well-structured ontology. The third research question is whether the complex ontology structure of these web elements could be implemented into a web-based tool. Again, relying on the selected technologies and using the manifested ontology structure, we have been able to create a web-based tool (WB-OS) for the first two phases of disaster management and the tool will be extended to cover for all phases of natural disasters. WB-OS is a valuable tool since it could be used as a guideline in creating WB-NDMS. Moreover, in answering research questions four and five, Delphi techniques will be applied to evaluate and improve the ontology structure and assess the relative importance of web elements. Furthermore, AHP will be used to identify the relative importance of web elements in the ontology structure. Once these relative values are identified, the ontology structure with values could be used to evaluate the structural completeness and quality of natural disaster websites, for answering the last question. As a result, web developers and managers could use this WB-OS as guidance in creating web-based natural disaster management systems. They can also use it for checking and evaluating the sufficiency, comprehensiveness, and quality of their sites. Hence it can contribute to the education and evaluation processes in creating web-based disaster management systems. Furthermore, our approach shows how one can model complex and semi-structured domains when little knowledge is available.

References