Towards the Use of Upper Ontologies for Refugee Emergencies in Disaster Management

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Abstract
Disaster information, such as information on earthquakes, tsunamis, floods, fire, hazard chemicals, hurricanes, etc., is usually rapidly changeable, ambiguous, and huge. It often involves data items from diverse domains on the web, some of which have similar meanings but appear structurally dissimilar in different data sources. A promising remedy is to provide a basis for common understanding of disaster management in a formally correct way. Formal upper ontologies provide rich vocabularies for describing an information system, and they form a basis for defining abstract data types that support interoperability among heterogeneous systems. Development of an ontology for Humanitarian Aid for Refugee in Emergencies (HARE) is presented throughout this work.

Keywords: Disaster Management, Ontology, Interoperability, Humanitarian Aid for Refugee in Emergencies, Upper ontology

1 Introduction
Success of disaster information management depends on finding and effectively integrating related information to take decisions during information distribution [1]. A survey in [2] reported that ontologies and current technologies can be used to identify and associate semantically corresponding concepts in the related disaster information in order that heterogeneous data can be integrated. An ontology is collections of information that provided by the Semantic Web technology. It gives advantages to determine common vocabularies for knowledge representation and specifies constraints on the relationships between objects in an application domain. Such advantages cause information to be given well-defined meaning and better enabling computers and people to work in cooperation [3]. The term disaster management is used to describe large-scale processes of disaster relief and disaster recovery. It may refer to an extension of local emergency management. Disaster management is typically not an isolated process. It must be quickly aware of information from many sources and also must feed information externally [4]. Nowadays, there are many software applications launched to facilitate disaster management tasks. Combining information from various sources in these applications is, however, often problematic. Semantic interoperability of disaster information is important in these applications, since they were not initially developed for integrating with each other. Semantic interoperability allows the applications to cooperate with minimal modifications [5].

In this paper, we focus our attention on development of an ontology for Humanitarian Aid for Refugee in Emergencies (HARE), which is an important part of the disaster management domain. The paper is organized as follows: Section 2 provides background and related works. Section 3 describes our ontology development methodology. Section 4 concludes the paper.

2 Background and Related Works

2.1 Ontologies
An ontology is a conceptualization of data domain, which has the formal explicit definition of concepts (known as classes) in the given domain(s), properties (known as attributes) describing various features of the concepts, restrictions on these properties and well-defined relationships between concepts. The instances to represent the concept of ontology are known as
Individuals for the formal concept definitions, constitutes a knowledge-base. The target of ontology in Information Science is to define a common vocabulary and describe words and their interrelationships on a formal and hierarchical level. In addition, the ontology is also to enable knowledge sharing and data consistency [6].

2.1.1 Ontologies and Disaster management

Disaster management will have the success of management as getting the right resources to the right place at the right time; to provide the right information to the right people to make the right decisions at the right level at the right time. Interoperability is one challenging when involving organizations try to integrate these individual data sources [7; 8; 9].

The three types of interoperability are system interoperability, syntax and structure interoperability and semantic interoperability. During disaster management, they also have problems with interoperability at a system, a syntax and a semantic level. A system and syntax level has been achieved by hardware improvement and a syntax standard respectively. For semantic interoperability, a standard terminology is dependent upon the context of use and users [10]. The use of different terms and approaches cause confusion in the specification of universally accepted entities, concepts, rules, relations, and semantics. The basis of an ontology can cope with the confusion because an ontology is a logical theory accounting for the intended meaning of a formal vocabulary [1; 11].

Therefore, the disaster management domain is still a lack of a terminology and relationship among other data sources. From those causes, the semantics of disaster information are unclear for integrating systems, so that the use of ontologies is to better allow information interoperability and information sharing to exchange their information immediately in a short time period. Ontologies are similar to a conceptual schemata in database systems, but ontology provides a logical description to allow application systems to integrate together without having to share data structures. Because of the potential of an ontology, one data source can be combined with another. Thus, the need for ontologies to establish a common specification to deal with the entire disaster management cycle is necessary.

2.1.2 Upper ontology

An upper ontology can be also called as a top-level ontology or foundation ontology, which describes the general concepts for all knowledge domains. As general concepts, several ontologies can be hierarchical implementation on the upper ontologies. Although upper ontology has several advantages, such as integrating with existing ontologies, providing a predefined set of ontological entities, turning away from conceptual ambiguity, however, semantic interoperability between ontologies is the main advantage of upper ontology [12; 13; 14]. Based on reviews of the characteristics of ontologies to be used as upper ontology, we decide that the below ontologies meet most of our requirements.

2.1.3 Related upper ontologies

- Semantic Web for Earth and Environmental Terminology (SWEET) The SWEET ontologies include several thousand terms, spanning a broad extent of Earth system science and related concepts (such as data characteristics). To support such a large collection and adhere to the guiding principles, the concepts are divided, where possible, into orthogonal dimensions or facets in support of reductionism [15].

- Suggested Upper Merged Ontology (SUMO) It is the most outstanding proposal under consideration by the IEEE Standard Upper Ontology (SUO) working group. Its effort is to link categories and relations that come from different top level ontologies in order to improve ontologies in the Semantic Web area. SUMO is based on the fundamental distinction between Physical and Abstract. The goal of SUMO is to develop a standard ontology that promotes data interoperability, information search and retrieval, automated inference, and natural language processing. SUMO is implemented in the first-order logic language SUO-KIF that can be automatically translated into OWL, although the translation is lossy. The ontologies that extend SUMO are available under GNU General Public License [16].

- Friend of a friend (FOAF) An ontology which used to describe people, their ac-
tivities and their relations to other people and objects. The FOAF is useful in social networks with decentralized technology for connecting public web sites [17].

- **Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE)**
  DOLCE belongs to the WonderWeb library of foundational ontologies that provide a set of upper level concepts. It aims at capturing the ontological categories, and underlying natural language and human common sense that assist in making formed conceptualizations explicit. Furthermore, a combination of DOLCE has been published to improve some parts of DOLCE. DOLCE is based on the fundamental distinction between Endurants (i.e., objects or substances) and Perdurants (i.e., events or processes) [18].

### 2.2 Humanitarian Aid for Refugee in Emergencies (HARE)

Disaster management has four phases, which involve mitigation, preparedness, response, and recovery when natural or human-made disaster occurs [19]. The mass of information is spread over countries in crisis. It is necessary to develop information systems to support that huge information. An IT infrastructure must be established as an information controller in each system. The HARE is one component that emphasizes the response and recovery phases. The objectification of HARE is under an obligation to lead and coordinate international action from the world-wide protection of refugees and manage the resolution of refugee problems. This paper presents a novel concept under the UNHCR operations [20]. The UNHCR stated that a refugee emergency of UNHCR is any situation in which the life or well-being of refugees will be threatened unless immediate and appropriate action is taken, which demands an extraordinary response and exceptional measures. The HARE has been cooperating with many systems both domestic and international. Obviously, information systems are critical for the HARE. In the past, various systems of the HARE were focused on a stand-alone system, but currently efficient systems should rely on other systems. Thus, the interoperability of systems is challenging. This paper tries to establish semantic interoperability of heterogeneous data from several operations of UNHCR.

### 3 Methodology

#### 3.1 Ontology building methodology

Ontologies provide semantic interoperability between people and systems by providing explicit specification of conceptualizations. Formal specification reduces an ambiguity in definitions. People generally use ontologies to express models of the problem domain. They also use ontology as a knowledge base to either extract new knowledge, or support several functions of their systems. In this paper, we apply the ontology for HARE domain from UNHCR’s subsystems, namely Refugee Registration System, Identification of Persons of Concern System, Emergency Planning System, Distribution of Assistance System, and Donation System to support the semantic interoperability. The establishment of an ontology for the HARE domain is a pre-requisite to developing an application. There are several methods to building ontologies. Most of the methods for building ontologies are focused on the conceptualization and ontology implementation, but they do not pay enough attention for integration of the ontologies [10; 21]. We adopt the following three steps from Uschold and Kings method [22]:

1. **Identify purpose**: to consider the requirement of Refugee Emergencies ontology and create the process models

2. **Ontology capture**: to consider knowledge models from the process models

3. **Coding and integrating**: to implement the Refugee Emergencies Ontology and integrate with upper ontologies

#### 3.1.1 Identify purpose

In order to establish the ontology requirements, we have read the overall operations of the HARE from the literature on Handbook for Emergencies [20] to undertake the abstraction and processes of refugee emergencies from UNHCR, and we learnt that the HARE has responsibilities for resolution of refugee problems. The operations of UNHCR cover many areas in refugee emergencies, including health, food,
sanitation and water, as well as key field activities corroborate the operations such as logistics, community services, and registration. Such operations must be managed and controlled by many associate organizations. In the identify purpose step, information should be extracted carefully from documentations. Misunderstanding in this step could lead to misinterpretations in next steps. We determined the domain, scope and purpose of the operations into the refugee emergencies process models that depict the principle of refugee emergencies’ operations.

**Process 1: Refugee Registration**
This process is capturing the implemented process of the refugee registration in an emergency process model. Refugees should be registered as fast as possible after reach to a refugee center. Refugee profile must be the first information that organizations would like to know. The following information is recorded for a person of concern individual verification: Name, Unique identifying registration number, Date and place of birth, Sex, Existing identity documents, Marital status, Special protection and assistance needs, Level of education, Occupational skills, Religion, Language, Household and family composition, Date of arrival, Current location and address, Place of origin, Photograph. This information will be collected to be the properties of Refugee profile concept.

**Process 2: Identification of Persons of Concern System**
After the refugee registration process, if time permits, a pre-screening should take place at this stage to identify those who may not be of concern to UNHCR. The refugee profile will be analyzed for refugees needs assessment. An accurate estimate of numbers of refugees is a prerequisite for effective protection and assistance, and identification of beneficiaries, including persons with special needs.

**Process 3: Emergency Planning System**
The planning process is very important. Efforts should be made to design and implement a shelter as soon as possible. Several organizations must rely on this planning system. The project is the structural planning for such as the training, logistics, telecom, security, sites(camp, shelter), etc. This will enable better management such as shelter management, non-food and food items’ distribution.

**Process 4: Distribution of Assistance**
There is a simple system to handle the distribution of assistance and provision of service to refugees, including emergency health care, distribution of food and non-food items. Many staffs from organizations participate in this system for sharing help to refugees.

**Process 5: Donation System**
The Donation system is designed to receive, manage, and distribute a mass of donated goods and services. With the help of refugee communities, they identify refugee individuals and groups with their needs, especially unaccompanied and separated children. This system operates with the distribution through an assistance system to support needs of refugees.

3.1.2 Ontology capture
In the second step, the refugee emergencies process models from the previous step will set the initiation to establish ontological conceptualization, which is the key to the HARE ontologies. In this step, we developed the Unified Modeling Language (UML) Use Case Diagram that is used to create the functionality for the system to graphically represent and envision the concepts and relationships between elements. This paper selects five principles of the HARE in order to understand an extent to which interoperability can be supported. (Fig.1-5)

3.1.3 Coding and integrating
In the Refugee Emergencies ontology implementation step, the core concepts and the existing relations from use case diagrams help to build the scope and role of the ontology. Each use case consists of detail to extract relevant classes, their scopes and the required detail. Firstly, a first set of terms is gathered by analyzing use cases. The selected terms are consid-
Figure 2. Identification of Persons of Concern System Diagram

Figure 3. Emergency Planning System Diagram

Figure 4. Distribution of Assistance System Diagram

Figure 5. Donation System Diagram

Figure 6. DOLCE upper ontology and HARE ontology

The main concepts of the proposed ontology are the Refugee, Person, and RefugeeActivity concept. Those concepts can be defined by the expertise as the core concepts of Refugee Emergencies ontologies. That core concepts in the operations of the HARE are Refugee, RefugeeActivity, RefugeeNeed, Commodity, Person, Plan, Project, Organization, Staff. After the core concepts are defined, subclasses and disjoint decompositions are also identified, such as a food product is a particular type of Commodity. A commodity is characterized by Unit. Each commodity should be assigned a unit, which means that a relation “hasUnit” between classes Commodity and Unit must be established (Fig.9). To get core concepts, the relations between concepts and axioms are important to define implicit meanings.

The implementation of the HARE ontology required to choose an appropriate ontology editor and development environment. The Protégé development platform which contains the Protégé-OWL ontology editor for the Semantic Web is chosen for using in this research. After creating ontology, we would notice that there are some classes in the ontology that can be hierarchical implementation on the upper ontologies. As the related upper ontology review, we found that the concepts of the upper ontologies, which are matched with the HARE ontology, are in the DOLCE, SWEET, SUMO, and FOAF. They can provide the basis for common understanding in HARE as shown in Fig.6-10.

**Use case 1: Refugee Registration** (Fig.1)
Refugee is a subclass of DOLCE: social role (Fig. 7).

Refugee has at least one hasResponsibility relationship to individuals that are member of RefugeeActivity (Fig. 8).

RefugeeActivity is a subclass of SWEET: HumanActivity and has SWEET: ConsumptiveUse, SWEET: Evacuation, and SWEET: Work as its subclasses (Fig. 8).

Person is equivalent to DOLCE: natural-person (Fig. 7) and an individual of Person has only 1 string to FOAF: family-Name, FOAF: firstName, and FOAF: lastName DataProperty (Fig. 10).

Use case 2: Identification of Persons of Concern System (Fig. 2) The main concepts of the proposed ontology are Refugee and RefugeeNeed concept. This concept can be defined by the existing ontology as follows:

- Refugee has at least one requires relationship to individuals that are member of RefugeeActivity (Fig. 8).

- RefugeeNeed is a subclass of SWEET: HumanNeed and has SWEET: DrinkingWater as its subclass (Fig. 8).

Use case 3: Emergency Planning System (Fig. 3) The main concepts of the proposed ontology are Plan, Project, and Commodity concepts.
This concept can be defined by the existing ontology as follows:

- Plan is equivalent to DOLCE: plan and DOLCE:plan has at least one DOLCE:proper-part relationship to individuals that are member of DOLCE: goal or DOLCE: objective (Fig.6).

- Project is equivalent to DOLCE: project and DOLCE: project is a subclass of DOLCE: plan (Fig.6).

- Commodity is a subclass of SUMO: product and has food product, and non-food product as its subclasses (Fig.9).

- Commodity has only has-unit relationship to individuals that are member of SUMO: UnitOfMeasure (Fig.9).

- FoodProduct has SUMO: food product and SUMO: beverage product as its subclasses and NonFoodProduct has SUMO: wearable item as its subclass (Fig.9).

Use case 4: Distribution of Assistance (Fig.4) The main concepts of the proposed ontology are Refugee, Commodity, and Organization concept. This concept can be defined by the existing ontology as follows:

- Organization is equivalent to DOLCE: Organization (Fig.7).

Use case 5: Donation System The main concepts of the proposed ontology are Commodity, Refugee, and RefugeeNeed. So that the concepts in this use case are as same as the above concepts that we mentioned.

After we completed all above steps, our HARE ontology has 89 concepts, 17 object properties, 26 data properties, and 82 individuals (Fig.11). The ontology we created can be used to be a common conceptualization of HARE that other related systems would be integrated with in this domain.

4 Conclusion

Semantic interoperability is critical to Disaster Management information sharing and reusing knowledge. In this paper, we proposed the semantic interoperability to the HARE domain base on the UNHCR. We presented the HARE ontologies design choices, and adopted an ontological approach for semantic interoperability to be the common understanding of any information. We presented our ontology design based on an ontology development method and considered the requirement from many documentations that reflect the humanitarian aid system in reality. In addition, after we design the HARE ontology, we provided a comprehensive review of related upper ontologies, which can be integrated with our ontology. The upper ontologies help avoiding ambiguities in the large-scale information integration. Therefore, we believe that the proposed HARE ontologies with upper ontology integration are reasonable for reducing problems on semantic interoperability. The suitable interoperability between the HARE systems can make the efficient access to humanitarian aid during disasters and the ability to save a greater number of lives. Despite being an initial exploratory research, this work is an important step towards exploring in the greater detail and implementing the Semantic Web technologies in the Disaster Management domain.

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